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REPORT

ON THE

CHROME IRON ORE DEPOSITS

IN THE

EASTERN TOWNSHIPS
PROVINCE OF QUEBEC

BY
FRITZ CIRKEL, M.E.

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REPORT

ON THE

CHROME IRON ORE DEPOSITS IN THE EASTERN TOWNSHIPS, PROVINCE OF QUEBEC.

BY

FRITZ CIRKEL, M.E.

INTRODUCTION.

The rapid progress in the production of chrome iron ore in Canada, since 1902—as seen from the statistics published—seems to indicate that the work of mining and refining this ore is destined to become of considerable importance among the industries of the Dominion. Up to the year 1902 there was no steady production, and the chrome iron ore deposits were only superficially tested and operated; while their peculiar occurrence added so materially to the difficulties in mining, and to the cost of preparing it for the market, that there was no reasonable margin of profit.

To-day we find entirely different conditions. The deposits once dicovered on the surface have, in the majority of cases, been followed towards depth; more rational and practical mining methods have been adopted, while the method of concentration of the mineral has been brought to such perfection that few improvements in that respect are to be anticipated.

In the present report an effort has been made to summarize all practical information now available regarding this mineral, and it is hoped that the same will be of interest not only to those engaged in the mining and exploitation of chrome iron ore deposits, but also to those interested in this mineral or its products commercially. The literature on the subject is so meagre, and so scattered through technical journals, and government reports, that it has been very difficult to study the industry in all its phases. The writer proposes to discuss in this report the geological occurrence of the mineral, both in Canada and foreign countries; the shape and structure of the ore bodies; their manner of development; the composition of the ores and their properties; the various methods of concentrating, and finally the application of chromium, its alloys and compounds.

As to concentration, the writer has confined himself to the enumeration and description of machinery for crushing and separation purposes, which so far has been generally adopted in the mills. He has also summarized the principles upon which the concentration of chromic iron from the accompanying gangue is based, with an outline of mill schemes.

The sketches of the ore deposits have been made from nature, while all the plates have been prepared from photographs, mostly taken by the writer.

CHAPTER I.

HISTORICAL.

The history of chrome iron ore commences with the discovery of the element chromium. Two dates are given for the discovery of chromium, 1794 and 1797; but as it was made in France, we may reasonably suppose that this discrepancy is due to the fact that nearly all French scientific journals were suspended from 1793 to 1798. When they resumed, some of them were antedated as much as four years. During the latter part of the eighteenth century the mineral crocoite (Dana lead chromate Pb CrO_4) was an object of criticism by many chemists, for the reason that it was known to contain a foreign substance, at that time not classified. In 1762, Lehmann, in a letter to Beuffon, "De nova minerae plumbi specie crystalline rubra," described a new mineral from Siberia. In 1786 Lehmann analysed it, and found that it contained chiefly lead, and that the "mineralizers" were arsenic and sulphur. In 1797, Vauquelin, at that time professor of chemistry in the Ecole Polytechnique of Paris, examined the same mineral, and stated that it contained an intimate mixture of iron, alumina, and lead peroxide. The account of this work was published over the name Macquart, a chemist of repute, associated with Vauquelin in the investigations.[1]

Previous to Vauquelin, Klaproth, a German chemist, took up the problem; but his results were anticipated by the discovery of Vauquelin. Publication of Klaproth's work was made in a letter, which the editor of Crells Annalen[2] had asked of him, and which stated that he had dissolved Siberian lead ore in hydrochloric acid, and after freeing the solution from lead chloride, had saturated it with sodium carbonate which precipitated "Metallic kalk" as it was called. A small sample of this "metallic kalk" (which was doubtless, chromic oxide) he enclosed in his letter. He also adds that he had fused it on charcoal, with microcosmic salt and with borax, and he gives also the characteristic beads resulting.[3]

In his chemical dictionary, under the caption Chromium, Klaproth gives a brief statement that he had suspected the presence of a new metallic substance in the lead ore, and that Vauquelin had anticipated his work.

Vauquelin experimented for a considerable time with the new mineral (crocoite) and he found that the same was a native crystallized salt of lead, the acid of which was easily reduced to an oxide, which he believed to have a metallic base. He subsequently reduced the oxide, isolated the metal, and in describing the characteristics of this element adopted the name chrome, which since then has been accepted in chemistry.

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[1] Chrome in the Southern Appalachian Region, W. Glenn, Trans. Am. Inst. M.E., Vol. xxx, p. 480.

[2] Chemische Annalen, Helmstadt, 1798.

[3] Chrome, Ibid, p. 483.

The "Annales de Chimie" of January 19, 1798, contain an account of this important work, under the heading:[1] "Mémoire sur une nouvelle substance métallique, contenu dans le plomb rouge de Sibérie, et qu'on propose d'appeler chrome, à cause de la propriété qu'il a de colorer les combinaisons où il centre. Par Vauquelin. Lu à la première classe de l'Institut nationale le II Brumaire, an VI (1798)." The author describes minutely the work previously done by Macquart and himself: he states that Blindheim had found many bodies in the mineral, including molybdic acid. From the statement in Vauquelin's work, there is no doubt that he had identified some of the oxides of chromium. In another mémoire, published in the same volume, Vauquelin details the method by which he isolated the metal chromium "Le II Brumaire, an XI" (after the new era commenced with the French revolution) which corresponds to November 4, 1797, and this date may be considered as that of Vauquelin's discovery of chromium.

Vauquelin soon found that the salts of chromic acid, and especially the chromium oxides, had beautiful colouring powers, a fact which led him to think that these salts might have important applications in the technics and arts. However, the supply of crude ore was very limited, and in 1798, according to W. Glenn,[2] the only commercial ore of chromium as yet known to science was described for the first time as, the mineral "*chromic iron*," by P. Meder, in an article entitled: "Description of some new Russian Minerals." Meder reported that the discovery of this ore was made by Mr. Soymonof, the director of mines for the northern part of the Urals, on the bank of a small river in that section of the country. This ore was analysed by Professor Lowitz, who found in it a composition of chromic acid, iron, some silica, and alumina. It was found that the chromium contents in this mineral were so abundant, as to be extracted in quantities for use as colouring matter to be applied in the arts. By fusing a mixture of the powdered mineral and potash nitrate in a pot, the oxide was converted easily into chromic acid, and finally into potassium chromate, which, in a comparatively pure state, could be separated by water, from those parts of the ore—insoluble in that menstruum. The next step was to treat the yellow solution with a mineral acid, whereby the potassium chromate was compelled to yield to the acid one [illegible] of its potash, forming potassium dichromate, which was readily sepa[illegible] by crystallization from the mother liquor.

Another discovery of chrome iron ore, contemporaneous with that made in the northern part of the Urals, was that made in the southern part of the same province, about 500 Russian versts distant from Soymonof's discovery.

In 1799 Tassaert, a French chemist, analysed an ore from the Department of Var, France, and published the results under the title "Analyse du chrome de fer de la bastide de la Carrade."[3] The author begins with a physical description of the mineral, in which he states that it resembles brown blende. Although he makes no mention of Lowitz' work, the mention of his name leads us to suspect that he knew of it, for Lowitz tells how to differentiate chrome iron ore from that which Tassaert had under investigation, namely, uraninite. By serious errors and deductions Tassaert found, by means of fusion with potassium hydroxide, chromic acid in his mineral, while as a matter of fact no chromium was present. It might be mentioned that in the year 1881, Morse and Day at that time working in the Johns Hopkins University printed a paper on the "Assay of chromic iron by the method of fusion with potassium hydroxide." It seems that they had worked out the means of decomposition used in the first analyses made of that mineral.

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[1] Ibid, p. 482.
[2] 17th Annual Report U.S. Geol. Survey, p. 261.
[3] Ibid, pp. 261-2.

In 1829 Köchlin found that chromium salts were well suited to dyeing Turkey red. Shortly afterwards they were found to be adapted to the production of several bright colours in textile fabrics, and in painting; especially in the dyeing of wool, and the decoration of porcelain. The excessive cost of the salts, principally due to the high costs of potash nitrate, and of the reduction of the ore to powder, restricted their economic use.

Previous to 1827 the production of chromic acid salts was very limited; for the methods of manufacture were crude, and the supply of chromite precarious, while its cost was almost prohibitive. The information regarding the sources of early supply is very meagre; but it seems that they were chiefly in the Urals, not far from Ekaterinburg, and in the drainage basin of the streams which finally find their way to the Arctic ocean through the river Obi. The ore was loaded on rafts and thus floated to navigable waters, after a journey lasting often through two summers.[1] Thence the ore found its way to the Arctic, and finally was landed in western Europe. In 1827 discoveries of chrome iron ore made on the North American continent entirely altered the status of the industry. It was the Baltimore region which supplied practically the world's consumption of chrome iron ore from 1827 to about the beginning of the Civil War.

The account of the discovery of chrome iron ore in Baltimore county makes interesting reading. According to W. Glenn,[2] in the summer of 1827, Isaac Tyson, Jr., saw in Belaire market, at Baltimore, a cart containing a cider barrel, held from rolling about by means of some heavy black stones. They consisted of chrome iron ore; and the knowledge necessary to identify them was at that time confined perhaps to young Tyson, who happened to see them. He had made a study of them in their first known American locality - that of the Bare hills near his father's residence then six miles north of the city. He had also studied chromium compounds in the early French literature on the subject, and had possessed himself of about all the available knowledge thereon. These stones had been taken from the surface of a farm in Harford county, 27 miles northeastward from the city.

[1] W. Glenn, Am. Inst. M.E., vol. xxv, p. 486.
[2] Ibid.

In 1828, Mr. Tyson discovered chrome iron ore on the so-called Wood farm, in Lancaster county, Pennsylvania. This property has been worked since that time up to the present except from 1868 to 1873 and has yielded over 100,000 tons of high grade ore. In addition to the above sources of supply, a number of subsequent discoveries were made at Rock Springs, Maryland, and several other places of minor importance.

In 1848, large deposits of ore were discovered by Professor Lawrence Smith, near Brusa, in Asia Minor, about 57 miles southeast from Constantinople. Near Harmanjick, 10 or 15 miles south from this locality, another deposit of large extent was found. For some reason, however, the Turkish deposits were very slowly developed, and it was not until twelve years afterwards about 1859—that their full importance was felt in Europe and America. Since that period they have practically supplied the markets of the world. For many years these ores, on account of their excellent quality and their comparative cheapness, were bought by Mr. Tyson for his factory in Baltimore.

In 1870, chrome iron ore was discovered in Del Norte county, in California, by prospectors sent out by Tyson, of Baltimore. For some years this deposit was worked, and large quantities of ore were extracted. Following the discovery in Del Norte county came that of Sonoma, San Luis Obispo, and Placer counties. Chromite is now known to be common throughout California, having been noticed in more than half the counties of the State. The undeveloped deposits, and mere croppings, are, in fact, too many to admit of enumeration.

The first reference to the occurrence of chromite in Canada is made in the Report of the Geological Survey for 1847-8. A deposit, in the township of Bolton, is described as occurring on lot 26, range vii, in a vein one foot thick, and a sample assayed by Dr. Hunt indicated 45·90 oxide of chromium; while a large block of 600 lbs. weight, picked up near the lower end of Memphremagog lake, indicated a vein of at least 18″, and gave on assay 49·75 per cent.

According to the Report of Progress for 1863, about 10 tons were, in 1861, extracted in the neighbourhood of Lake Nicolet, township of Wolfe. From 1886 to 1888 several discoveries were made in Wolfestown, Leeds and Thetford.

In 1884, according to Mr. Obalski's report, chrome iron ore was found near Black lake; and subsequently other discoveries were made in the vicinity, especially in the township of Coleraine. It is in this township that the greatest development work has been carried on, and where mining and refining of the ore is now one of the principal industries.

METALLIC CHROMIUM AND CHROMIUM BEARING MINERALS.

Chromium is not a very common substance, and it does not occur in the native state. It is found in several minerals: in crocoite or lead chromate; especially in chrome iron ore, or chromite, which is the chief ore of chromium, and is the one usually employed in the manufacture of chromium and its compound.

Metallic chromium forms a light green, glistening, crystalline powder, exhibiting under the microscope aggregations of crystals of a tin white colour, and having a specific gravity of 6·81. The fused metal is usually as hard and tough as corundum, melts at a higher temperature than platinum, is not magnetic, and when ignited in the air, or in hydrogen, is only slowly oxidized. Heated in the oxyhydrogen flame it burns brightly, with emission of sparks, and when fused with saltpetre or potassium chlorate, is converted into potassium chromate. It readily combines with chlorine, and dissolves quickly in hydrochloric acid. Cold dilute sulphuric acid only attacks it slowly; but on warming it dissolves with evolution of hydrogen. Nitric acid, even when hot and concentrated, has no destructive action upon it.

Crocoite is chromate of lead, with the chemical formula $PbCrO_4$ that is chromium trioxide 31·1 per cent, and lead protoxide 68·9. This mineral was, during the latter part of the eighteenth century—as outlined in a preceding paragraph—an object of criticism from many prominent chemists; for the reason that, it was known to contain a foreign substance, at that time not classified. It was with this mineral, obtained from Siberia, that Vauquelin made his important investigations, which resulted in the discovery of chromium. On account of its scarcity, however, it is considered more as a mineralogical specimen than as a mineral of commercial utility.

Far more important from a commercial point of view is the metallic mineral called chromite.

CHEMICAL AND PHYSICAL PROPERTIES OF CHROME IRON ORE.

The principal mineral from which chromium and allied salts are derived is chromite, or chrome iron ore. This mineral resembles, in appearance, magnetite; in fact in the beginning of the industry magnetite was frequently taken for chromite. Isaac Tyson, of Baltimore, the founder of the chrome industry, once bought many tons of magnetic sand, when he supposed he was buying chrome iron sand.

When freshly broken the mineral chromite has an iron black, or somewhat brownish-black colour. Shipments of ore from the Turkish mines, however, have a yellowish shade of brown. But when freshly broken the ore is brownish black; and scratches window glass even when friable between one's fingers. It sometimes contains 32 per cent of protoxide of iron, and 68 per cent of sesquioxide of chromium; when its composition is represented by the symbol $FeOCr_2O_3$. It is a heavy, opaque mineral, of sub-metallic lustre. In very thin sections it is sometimes yellowish red. Its impalpable powder is invariably brownish, increasingly so the more chromic oxide is contained in the specimen. It is brittle, and its fracture uneven. Its hardness is 5·5 (Mohs' scale), and when pure has a specific gravity of from 4·32 to 4·56. Its structure is usually finely granular, and sometimes massive.

The mineral when freshly mined is exceedingly tough under a blow from the hammer; while other ores, and sometimes those exposed to atmospheric action, may be rubbed easily to granules.

Asiatic chrome iron ores are friable, and shipments contain many small lumps and are in a finely pulverized state. Canadian chrome iron ores are very hard and tough; hence stand transport and handling, and contain many large sized blocks. Some ores of the Turkish mines are very friable; indeed they contain scarcely any lumps, and are mostly in a condition resembling fine gravel and sand.

Chromite crystallizes in the isometric system, in octahedral form. Crystals are exceedingly rare, though some have been found in Tyson's big Wood mine in the Pennsylvania region. Some crystals have been found in sand chrome; but they cannot be recognized as such with the unaided eye. The largest crystal ever found was that discovered by Mr. W. Glenn, which measured about 6 millimetres in length through its greatest axis. This crystal is said to be a perfect octahedron, and is now in the collection of Prof. William Simon, at Baltimore.

It is sometimes feebly magnetic, but can be distinguished in this respect from magnetic iron. In the above formula $FeO_1Cr_2O_3$, one or both of the metals are always more or less replaced by alumina, magnesia, lime, and silica, together with other gangue minerals which occur in very small quantities. As a general rule a part of the chromic oxide is replaced, so that ores containing more than 50% are really not plentiful. Mr. W. Glenn, an authority on chrome iron ore, asserts that the exhibit of Russia at the Centennial Exposition, at Philadelphia, contained a specimen marked 59% chromic oxide. But he adds that he has never seen any ore richer than 56%. This was obtained from a hand specimen, while an actual shipment by his own assay gave 54%. The varieties containing little chromium (up to 10%) are hardly more than varieties of spinel, and are classed under picotite or chrome-spinel. Its chemical formula is $(Mg.Fe)\ O.\ (Al,Cr)_2O_3$, being a representative of a mineral approximating spinel, $MgOAl_2O_3$, in which the magnesium is largely replaced by iron and chromite.

Chromite is infusible before the blowpipe in the oxidizing flame. In the reducing flame it becomes slightly rounded on the edges, and feebly magnetic. With borax and salt of phosphorus it gives beads, which, while hot, show only a reaction of iron, but on cooling become chrome green; the green colour is heightened by fusion of the bead on charcoal with metallic tin. It is inappreciably acted upon by acids, but can be decomposed by fusion with potassium or sodium bisulphate.

CHROMIC OXIDE PRESENT IN OTHER MINERALS AND ORES.

Chromic oxide is found very often in titaniferous ores, and it is possible that it enters these ores—although rarely determined—in some form of spinel.[1] The titaniferous ore richest in chromic oxide, so far known, occurs at Chugwatercreek, in Wyoming, U.S.A., with 2·45 Cr_2O_3. In the Adirondack labradorite rocks, [illegible] to one per cent Cr_2O_3 has been found; while at least traces of chromic oxide are almost invariably present in the Adirondack titaniferous ores.

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[1] Nineteenth Annual Rept. U.S. Geol. Survey, p. 390.

A bright green coloured mica, which contains in combination a portion of oxide of chromium, is found in several localities in the Eastern townships of the Province of Quebec.[1] Minute scales of this mica occur in the magnetite of Sutton; and it is met with in large plates and imperfect crystals, in a dolomite from Bolton. This mica is probably allied to the chromiferous mica from the Tyrol, which has been named fuchsite.

Oxide of chromium, in small amount, is found in an unknown state of combination, in an impure earthy unaltered limestone from Granby.

A beautiful chrome garnet is found on the south lot of range xii. of Orford.[2] It forms granular masses, or is disseminated with millerite (sulphide of nickel), in a white crystalline calcite. The largest crystals are found in druses in the massive portions, but they do not exceed a line in diameter, and are dodecahedrons, sometimes with their edges replaced. This mineral is transparent, with an emerald green colour, which is not altered by a red heat. Its analysis gave:—

Silica	36·65
Alumina	17·50
Oxide of chromium	6·20
Protoxide of iron	4·97
Lime	33·20
Magnesia	0·81
Volatile	0·30
	99·63

This garnet, if obtained in sufficiently large crystals, would constitute a commercial gem equal in beauty to the emerald. A similar garnet is found associated with apatite, pyroxene, calcite, orthoclase, tourmaline, and idocrase, in the township of Wakefield, Ottawa county.

A very bright grass-green mica, which entered largely into the composition of the gangue of a specimen of nickeliferous pyrrhotite from lot 6, range i, of the township of Hyman, district of Algoma, Province of Ontario, has been examined, and proved to be a chromiferous biotite.[3]

The argillites, and quartz, in many of the mines of the Greenhorn mountains, Oregon, contain greenish spots, which have often been mistaken for copper, but which in reality consist of finely divided chrome mica, or fuchsite. The same mineral also occurs at the Golconda mine, near [illegible]pter, Oregon, having a stain somewhat bluish in tint.

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[1] Report of Progress, 1863, p. 494.

[2] Ibid, p. 497.

[3] Rept. Geol. Survey of Can., 1892–93, p. 27 R.

Chromiferous iron ores have been mined lately in Greece; and although they are not rich in iron, containing rarely more than 50%, yet they are abundant enough to form the basis of substantial mining operations in several localities. According to A. Habets[1] the chief locality is north of Athens, particularly in Boetia and Locrida. Here large masses of serpentine have been injected among white and yellow limestones; the iron ores associated with the serpentine being found in veins: sometimes in the serpentine itself; sometimes at the contact of serpentine and limestone, and sometimes in fissures in the latter rock.

The concessions of the Société Hellenique des Mines are situated north of Mt. Ptoon. The principal deposit, over 2 km. (about 1 $\frac{1}{7}$ mile) long is in the form of a vein between a roof of yellow limestone and a foot-wall of white limestone. The vein dips 15° to the southwest, and its width varies from 12 to 18 metres. In another deposit north of the first, the vein reaches a width of 110 metres, but includes a limestone horse. This deposit is now being operated. These concessions are connected with the wharves at Larymna, on the Atlanta canal, by a railway 16·5 km. long.

Two partial analyses of the ore, dried at [illegible]10° follow:—

	I. Per cent	II. Per cent
Iron	47·50	49·10
Manganese	0·56	0·05
Chromium	2·19	2·45
Nickel	0·70	0·56
Alumina	12·35	n. det.
Lime	0·99	0·32
Magnesia	1·61	0·70
Silica	6·38	5·39
Titanic oxide	0·60	0·45
Sulphur	0·016	n. det.
Phosphorus	0·03	0·024
Arsenic	0·01	0·029
Copper	0·01	0·017

The output of the Société Hellenique in 1907 was 185,000 tons.

THE OCCURRENCE OF CHROME IRON ORE.

The character of chrome iron ore is practically the same in its general constituents whatever the source; although it varies in the amount of chromic oxide—ranging from 40 to 50%. In the chemical composition of chromite FeO, Cr_2O_3 part of the chromium may be replaced by ferric oxide and alumina, or the ferrous oxide may be partially replaced by magnesia. Silica often accompanies the ore as an impurity.

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[1] R[illegible] des Mines et de la Metall, Febr., 1908.

As chromite is a mineral that suffers but slight alteration, most occurrences doubtless represent the original, and not the altered form. In some of the North Carolina chromites a beginning of alteration has been observed by Dr. Wadsworth, in chromite from Buck creek, in which translucent grains are surrounded by an opaque mantle, through loss of alumina and chromium oxide.

It cannot be said that chrome iron ore deposits are widely distributed over the globe; because the number of localities, although appearing quite numerous, do not all contain chromite in commercial quantity. Most of them have ore of impure and undesirable character, while many are so remote from transportation facilities that only a few of them can have any economic value. In some instances the deposits apparently contain a sufficient quantity of the ore; but upon closer examination are found to be so intimately mixed with foreign substances, that it is impossible to separate the clean ore at a sufficiently low cost for it to commercially enter into competition with purer ore obtained from other deposits.

The deposits of chromite, according to their manner of deposition, may be divided into two classes:

(1) Primary deposits.

(2) Sand, or secondary deposits.

The sand, or secondary deposits are mostly of too low grade a character to be commercially useful. They are the natural result of disintegration of the rocks in which chrome iron ore occurs. Heavy rains wash these rock particles on the hillsides away, and deposit them in the valleys, the heavier particles passing to the bottom of the deposit, while the lighter, or rock particles are being carried away. In this way a natural concentration of the ore has been effected, though in most cases this concentration has not been carried far enough to allow the ore to be economically used. For this reason sand deposits are not, as a rule, looked upon with favour, and most of the higher grade ore is at present obtained from the solid or primary deposits.

Chromite is always found in association with serpentine, which has resulted from the alteration of basic rocks consisting of olivine, hornblende and pyroxene. These minerals at least the pyroxenes contain chromium as a base, but there seems to be no doubt that in the unaltered rocks chromite itself has formed one of the component minerals; just as magnetite so commonly occurs in this relation. We have to look, therefore, for chrome iron ore deposits to those formations in which serpentine forms one of the main constituents.

Chromite is sometimes associated with other economic minerals. Thus in North Carolina the peridotites contain corundum, together with chromic oxide; but it is stated that, the largest deposits of this mineral are found in places where there is a scarcity of chromite, and that little or no corundum has been found where the larger deposits of chromite occur.

Platinum is frequently associated with chromite in alluvial deposits, and also in placer deposits in various parts of the world. Thus in many of the counties in California chromite placer deposits contain an appreciable amount of platinum grains. On the eastern slope of the Urals, platinum has been found associated with chromite, which is disseminated through an olivine rock.

Messrs. A. L. Hall and W. A. Humphrey, in their pamphlet "On the occurrence of Chromite Deposits along the Southern and Eastern Margins of the Bushveld Plutonic Complex," May 18, 1908, refer to the association of platinum and chromite in the Ural as follows:

"The above-mentioned occurrence of platinum in some of the chromite deposits is of great interest, on account of the close general resemblance to the conditions under which this heavy metal is found *in situ* in some localities of the Ural. The bulk of the present supply is still derived from alluvial deposits, and for many years it was only known in this form. More recently, however, several cases have been described where the parent rock of the platinum has been located, and the metal found *in situ* in payable quantities. The first description of an occurrence of this kind was given by A. Inostranzeff, from the Nischne Tagilsk district of the Eastern Ural, where the platinum was found embedded in a nest of chromite enclosed in a serpentinized olivine-fels (dunite). More recently R. Spring has described the alluvial platinum deposits of Nischne Tagil: where a central mass of olivine-fels is surrounded by a basic marginal facies of pyroxenite: and the author remarks on the fact that the richest alluvial deposits are found along those streams which run across the olivine rock near its boundary with the pyroxenite. Such features strongly resemble the distribution of basic rocks round the central more acid portions of the Bushveld Plutonic Complex, and suggest the possibility of finding alluvial platinum under analogous conditions in this colony."

Magnetite is associated with chromite in a recently discovered deposit 20 miles east of Pretoria, on the farm De Kroon. The analysis of the ore showed the presence of very small quantities of platinum and gold, and gave 36·10% chromic oxide, and 41·35% iron.[1]

It is not unusual to find nickel associated with chromite. It occurs at the Wood pit near Baltimore, in the form of genthite, a greenish mineral encrusting chromite, and deposited in the joints of the mine wall-rock. Similarly it is found in the mines of the Line Pit group. But the occurrence of this metallic mineral affords clear evidence that its presence is accidental; that it had been deposited from watery solution subsequent to the formation of its enclosing rock, and that it had been concentrated from those rocks by some process of chemical action.

GEOLOGY OF THE SERPENTINE AREAS.

As the study of the occurrence of chromite deposits is interwoven with that of serpentine rocks, the writer, before entering into a discussion of the deposits proper, has deemed it advisable to present herewith a description of the various serpentines found in Canada, based on investigations made by Mr. N. Giroux, Dr. Bayley, Dr. Bell, Dr. Harrington, Mr. Hugh Fletcher, Dr. Ells, Dr. A. P. Low, Dr. Frank D. Adams, and also by the writer, covering a period of over 20 years.

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[1] Zeitschrift fur Practische Geologie, May, 1908, p. 192.

The most important, and the one which is also the most interesting from a geological point of view, is the Archaean group of serpentines, consisting of the Laurentian, the Huronian, and the Cambrian serpentines.

The Laurentian serpentines are confined to the great Laurentian formation, which covers the greater part of eastern Canada. They are mostly associated with crystalline limestone, and occur in the latter disseminated in grains, varying in size, occasionally in scattered masses, and sometimes in interstratified beds. As a general rule these serpentines vary in colour from light green to very dark green shades. Pale yellow, and some greyish serpentines are very frequent. They occasionally contain red patches, caused by the decomposition of iron pyrites present in the rock. The Laurentian serpentine contains less oxide of iron, and more water than ordinary serpentines.

The most easterly occurrence of Laurentian serpentine is near Pisarinco cove, New Brunswick. Here crystalline limestones grey and white alternate with quartzites and diorites, and sometimes with argillites. Amongst these rocks serpentine can be noticed very frequently, but it does not occur in large masses. At one point limestone is enclosed in the bed of diorite, and both rocks are traversed by veins of serpentine, containing asbestos (chrysotile). On the west side of the narrows of the St. John river small patches of serpentine can be noticed in crystalline limestone, with a conglomerate of limestone pebbles.

Farther westward, in the Ottawa valley, in the townships of Grenville and Templeton, we find quite a development of crystalline limestone, containing scattered masses of serpentine of irregular ellipsoid form. These serpentines, with their associated minerals, have been fully described by the writer in his monograph on "Asbestos: its occurrence, mining, refining and uses."

Serpentine rocks similar to these are found in the seigniory of La Petite Nation, which adjoins the township of Grenville. In the vicinity of Calumet falls, on the Ottawa river, pale green serpentine, associated with brown phlogopite and apatite in the white crystalline limestone, occurs quite frequently. Farther westward, crossing the Ottawa river, we find serpentine in the township of Ramsay, Lanark county, Province of Ontario, about 30 miles southwest of the township of Templeton. On the surface, the serpentine in the latter locality is of a beautiful amber colour; but in most places the mineral is disseminated through a white crystalline limestone. In Lanark township serpentine is interstratified with limestone, and forms here a rock of striking beauty. In the township of Dalhousie, lots 23 and 24, range iii, the serpentine is interlaminated with a granular crystalline limestone.

South of the township of Dalhousie, in the township of South Sherbrooke, spotted serpentine limestone, resembling those at Templeton, may be noticed. In North Burgess, adjoining Dalhousie township, an almost pure serpentine has been found. About 20 miles farther south, in the township of Loughborough, county of Frontenac, white and coarsely crystalline dolomite is seen on lot 4, range x, and in Wollaston, on Hatchet lake, and at the head of Reindeer lake, serpentine of probable Laurentian age is reported to occur. Dr. A. C. Lawson, of the Geological Survey, reported having met serpentine in the Keewatin area, on the west side of Teggau lake, a tributary of Rainy lake. This rock is massive, and occurs there in a band, immediately followed to the west by hornblende schist, and to the east by another band of green hornblendic schists and altered traps. Another mass of serpentine, in very analogous position, is seen on South bay of Lake Despair, and Dr. Lawson reported this as occurring with some degree of constancy in the middle portion of the Keewatin trough, and thinks these serpentines are the altered remains of olivine rocks. A small boss of this rock has also been examined by the same geologist at the southwest end of Suckler lake, coming in with green schist.

Mr. W. S. Bayley, of the Geological Survey, has made microscopical examinations of these serpentines, and says that in many of them the forms of the original olivine can be clearly seen, although there is no trace of the mineral left. Dr. Lawson reports serpentine to be more largely developed on the island and shore of Shoal Lake narrows than elsewhere in the Lake of the Woods region. He mentions also a boss of serpentine projecting through the black hornblende schists in the immediate vicinity of their contact with the gneiss.

Many minerals are associated with the Laurentian serpentine, but very few are in workable quantity.

Small quantities of chrysotile have been mined for asbestos in the township of Templeton, but the fibre was so short that the mines were soon abandoned.

The magnetic iron ore formerly smelted at the Marmora iron furnace was obtained from lot 8, range i, of Belmont. This deposit presented a succession of beds of ore, interstratified with layers of greenish talcoid slate, and of crystalline limestone, with which are associated serpentine, chlorite, diallage, and a greenish epidotic rock. Iron of a superior quality was manufactured from this deposit.

Pyrallolite, a mineral similar to steatite in chemical composition, softness, and refractory properties, is often met with in the Laurentian series. A bed of it, associated with serpentine, occurs between the gneiss and the limestone on lot 13, range v, of Grenville. It may be traced thence into range vi, and appears to be in considerable quantity. The colour of this mineral is generally greenish-white, or sea-green. Some varieties of it are nearly white, and have the translucency of porcelain. Very dark-coloured nearly black varieties, have also been found, and this mineral is capable of being turned in a lathe, and wrought like soapstone, and has been made into small vases, inkstands, and similar objects. Much of the figure-stone, or pagodite, on which the Chinese carve various ornaments, appears to be pyrallolite. It was used by the aborigines to make pipes and ornaments.

The serpentine of lot 13, range v, Grenville, and of some parts of the township of Burgess, is of a pale green colour, marked with spots of oxide of iron, and forms a fine ornamental stone.

As the serpentine has been used from time to time, and sometimes in large quantities, for a number of purposes especially as a plaster, and roofing material it may be of interest to give some additional information regarding its physical and chemical properties. The Laurentian serpentines have a lower specific gravity, and contain less oxide of iron, and more combined water, than ordinary serpentine; analyses of some of these follow.[1] No. I is from Grenville, taken from a white crystalline limestone. Its colour varies from honey yellow to oil green, and its density is 2·47–2·52. No. II is a similar serpentine, of a pale wax yellow, from Calumet island. Its density is 2·36—2·38. No. III consists of grains of honey yellow serpentine, separated by dilute nitric acid from a white lamellar dolomite, from Grenville. No. IV is the reddish brown serpentine rock, or ophiolite, from Burgess.

—	I	II	III	IV
Silica	39·34	41·20	44·10	39·80
Magnesia	43·02	43·52	40·05	38·40
Peroxide of iron	1·80	0·80	1·15	7·92
Water	15·09	15·40	14·70	13·80
	99·25	100·92	100·00	99·92[1]

The Huronian serpentines are little known and of limited extent. According to investigations made by the Geological Survey, serpentine of Huronian age occurs at two points in Charlotte county, New Brunswick. North-east of St. Stephen, dark grey dioritic rocks occur, containing serpentine, diallage, and chromic oxide. About two miles north of St. Stephen may be seen ledges of coarse grained, dark grey granitoid diorite, having thin layers of picrolite or fibrous serpentine in the joints, as well as serpentinous matter in the body of the rock. In crossing these ledges towards St. Stephen, the rock becomes somewhat darker, and portions are met with exhibiting thin lamination, the laminæ being separated by layers of serpentine about ⅛″ thick. There seems to be some doubt as to the age of these serpentinous rocks, and although supposed to be of Laurentian age, they are here placed under the head of Huronian rocks. The presence of chromic oxide in them, and the want of crystalline limestone in their association with other rocks, give them quite a different character to those of the Laurentian series of this Province. The first outcrops of these serpentines which we know of, in a northwestward direction from those last mentioned, are on Lake Abitibi, where they are found to be associated with micaceous, hornblendic, and chloritic schists, fine grained hard quartzites, diorites, and dioritic schists. A small island in this lake is composed of strongly magnetic serpentine, with splintery fracture, resinous lustre, and weathering dull white. An analysis of this serpentine was made by Dr. Harrington, who found it to contain grains of chrome iron ore, and a very small quantity of nickel, besides silica, alumina, protoxide of iron, and magnesia.

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[1] Geological Survey, 1863, page 472.

According to Dr. Robert Bell, there is, in the middle of Pigeon lake, about one mile from the lower end of it, a small island composed of very dark green serpentine, with strings of calcspar and chrysotile. It weathers rusty, and Dr. Harrington, on analysis, found it to contain oxide of chromium, both in the form of small grains, and in chemical combination with the rest of the rock.

No mineral of economic importance has yet been found in these serpentines, but perhaps when the country where they are more abundantly met with is settled, deposits of chrome iron ore may be discovered.

The pre-Cambrian serpentines seem to be limited to the almost extreme easterly portion of the Dominion. Mr. Hugh Fletcher reports serpentine to occur in three different places:—

(1) In Macdonald brook, Cape Breton Island, where white, pyritous crystalline limestone, lemon yellow serpentine limestone, and pale-green brown weathering limestone, and tremolite in small fibrous tufts, occur between bluish-grey and red felsite and bluish-porphyritic felsite; (2) on Kelvin brook, in the same island, a cliff of coarse, reddish felsite, associated with greenish and red, mottled, soft serpentine, is in immediate contact with reddish coarse grit and conglomerate, along an irregular line which runs N. 9° E., and (3) on Campbell brook, eastern Nova Scotia, where some white crystalline limestone appears, some beds of which are covered on the surface with large knobs of light-greenish and white serpentine; but the hills are composed mainly of syenite. These resemble very much the Laurentian serpentines in colour, and in their association with crystalline limestones. No minerals of economic value were found in them.

THE CAMBRIAN SERPENTINES.

The Cambrian serpentines are those which are confined to the great serpentine belt that extends from southern Vermont, to Gaspé, in the Province of Quebec. They are by far the most important in the whole Dominion; not only on account of their very interesting geological structure being an altered metamorphic rock, but because they contain economic minerals in abundance, especially chromite and asbestos. This serpentine belt may be divided into three areas:—

(1) The area covering part of the townships of Bolton, Orford, Brompton, Melbourne, and Danville.

(2) The Thetford-Black Lake area, covering part of the townships of Ham, Wolfestown, Coleraine, Thetford, and Broughton.

(3) The area covering a part of the Gaspé peninsula.

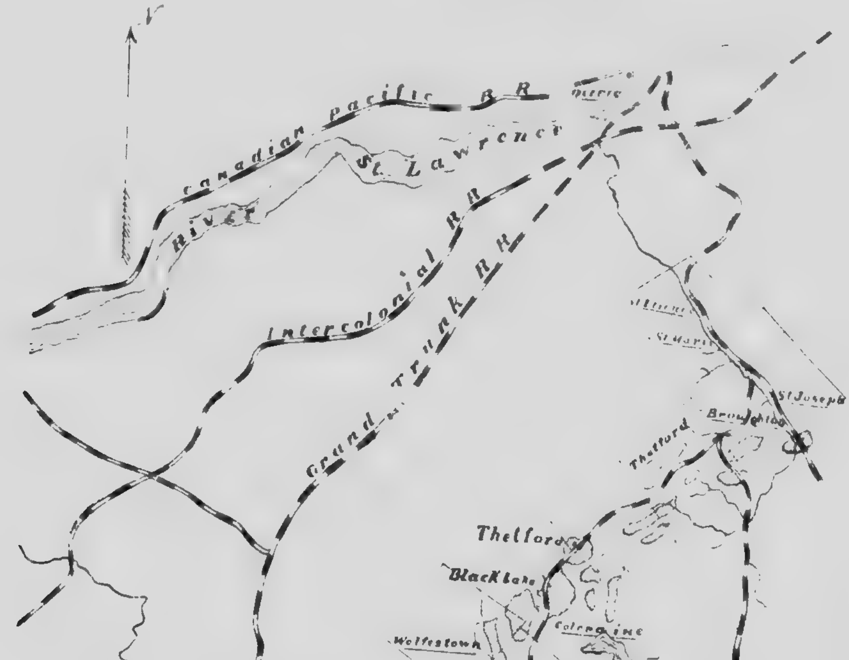

FIG. 1—Map showing distribution of Serpentine in the Eastern To , of Quebec, by Fritz Cirkel, M.E.

The first area, which may be termed the southwestern area, commences with the International Boundary Line, in Potton, and extends through the township of the same name, and through Bolton, Orford, Brompton, Melbourne, and Danville, and is characterized by a chain of hills extending beyond the boundary into Vermont. These serpentines, which are closely allied to a band of diorite and dioritic rocks, appear in irregular, but generally well defined masses; and, although showing here and there for the most of that distance, they do not deviate from their northeastward direction, but follow the general trend of all the formation, which is northeast. Along the course of this belt of serpentine, chromite exists at different points in several places in the townships of Bolton, Brompton, and Melbourne. Several attempts have been made at mining, but in nearly every case the mineral was found in too small a quantity to be of commercial value. It must be mentioned that the area under question is largely covered with heavy humus and forest growth, so that prospecting is very difficult; and the true value of this area, as regards the occurrence of chrome iron ore, can only be surmised. It is evident that unless the heavy forests are destroyed by fire and the soil removed — as in Black lake and Thetford — there is little chance that the presence of the mineral in paying quantities will ever be established.

The second, and most important field from an economic point of view is generally termed the Thetford-Black Lake area. It commences with several small knolls of serpentine, north of the Chaudiere river, and in the vicinity of that river between the villages of St. Joseph and St. Francis. In Broughton, Thetford, Coleraine, Wolfestown, and Ham, a great development of serpentine rocks can be observed, forming at times mountain masses from 700 to 1,000 feet above the surrounding country, and contributing largely to its generally rugged character by their sharp outlines and weathered surfaces. It is in this region that the world famed asbestos mines are situated — especially round Black lake and Thetford. This is the largest field of serpentine to be seen along the Atlantic seaboard of North America, and at present it is the most important one in Canada, since it contains all the productive asbestos and chrome iron ore mines of the Dominion. The serpentine mountains of Ireland and Coleraine townships extend over a width of from 5 to 6 miles, with a spur towards Little Lake St. Francis. Small outcrops of serpentine can be noticed on the Des Plantes river, and in range V of Cranborne, on the Etchemin river.

Nearly all the productive mines of chrome iron ore are located in this region; more especially in the township of Coleraine, and although no large workable deposits have been discovered beyond this locality, there is no reason whatever why, with extended and more vigorous exploration work, other productive mines should not be found.

Most of the serpentines occurring in the first and second area, as described above, are associated with dioritic rocks throughout the townships, sometimes in masses of large extent, as in the Big Ham and Little Ham mountains, and in the peaks along the western side of Lake Memphremagog; at other places as dikes. With these are often associated dioritic agglomerates, serpentines, and serpentinous breccias.

In the third area, that of the Gaspé peninsula, the serpentine present a very large development, especially in the Shickshock Mountain range, Mount Albert, and Smith mountain. It is found in bands, sometimes a few yards in breadth, interstratified with the slates and sandstones, and sometimes with diorites, in conjunction with which it forms knoll-like hills, or elongated ridges of considerable extent. In the exploration of the Shickshock mountains the serpentines of Mount Albert were found to contain small pockets of chromite, but there are very large areas of these peculiar serpentine rocks so concealed by forest and soil that prospecting is a very difficult undertaking.[1]

The serpentines of the townships form disconnected masses, generally of small extent, in the great series of slates, schists, and diorites, designated as a part of the Cambrian formation. Occasionally they assume such proportions as to form mountain ridges, as may be noticed in Black lake, where all the productive chrome iron ore mines are located on the great serpentine ridge, which attains a height of 900 feet above the track of the Quebec Central railway, and strikes in a northerly direction through the country. These serpentine masses, which may be considered as a secondary product, are unquestionably an alteration product from an olivine diabase or gabbro, which forms prominent hill features in this area.

In places, massive serpentines are in immediate contact with black slates, and in others very much broken and slaty serpentines, different in character, in colour and in touch, are found in what appears to be exactly the same black slates. Some of the serpentines are darker coloured, tougher, and better fitted for ornamental purposes than those of the Laurentian series. Ophiolites, which are chiefly mixtures of limestone, or of dolomite and serpentine — the latter predominating — are found in many places in the Eastern townships.

All the rocks in the district, from Vermont north to the St. Lawrence river, have been subjected to a great series of folding, and disturbances and evidences of this effect may be seen all through the serpentine region, in the decidedly slaty and schistose structure of parts of the serpentine masses. It may be stated, however, that most of the rocks in Thetford and Black lake, although exhibiting to some extent faults and slickensides, have withstood the strain of pressure, and are of a more massive character.

Slickensides and faults, as a result of these movements, are very frequent through the greater part of the serpentine region, and in some places have cut off entire working faces of chrome iron ore, presenting a barren wall for a time. In this case the cutting plane has a more or less polished surface, and is covered to some extent with soft slippery serpentine, thus concealing, sometimes, good ore beneath; and the miner should examine such walls very closely before deciding that they are barren.

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[1] Geological Survey Report, 1890–91, p. 20 S.

The serpentine exposed in different sections of this area varies considerably in character. Some of the rock is hard, siliceous and dry looking, as in some portions of Black lake, Ireland, and Wolfestown, and sometimes it exhibits a tarnished yellow colour. Very often seamy partings can be observed crossing the rock in every direction, and while it is true that they contain, in the majority of cases, only small accumulations of chromite, still they are sometimes indicative of the presence of the mineral in close proximity.

The serpentine of the Eastern townships presents several interesting features as a material for indoor decoration. Unfortunately it is easily affected by atmospheric agencies, and is not, therefore, adapted for outside work, since the polished surface speedily becomes tarnished by weathering. In earlier years attempts were made to obtain good sized blocks from some mines in Thetford, but while these can be extracted in large masses, the stone appears in many cases to be affected by joints and seams, which, in the dressing, interfere very seriously with the efforts to secure good, solid pieces for polished work. Slabs can, however, be readily sawn, which when well polished have a very rich and pleasing effect for interior decoration, and present a considerable variety not only in colour but in the markings.

Most of the serpentine in the chrome iron ore region contains a very small percentage of chromite, disseminated through the mass in an exceedingly fine state of division. Samples of the rock were granulated for the purpose of determining whether there could be any chromite extracted, but it was found that in some of them no grains or specks could be detected with the naked eye. These samples were then tested for chromite, and it was found that they contained from 0·73 to 6·32%.

A fibrous hornblende, which sometimes occurs in cracks and fissures through the chrome iron ore region, was subjected to the same test, and although quite a number of samples showed only traces of the mineral, yet in a few localities chromite was found to be present to the extent of 6·42%: even in parts of the formation which were quite distant from economic deposits.

A typical serpentine of the chrome iron ore region was subjected to analysis, and gave the following percentage composition:—[1]

Al_2O_3	1·84
Fe_2O_3	0·57
FeO	6·04
Cr_2O_3	0·04
NiO	0·20
CaO	0·18
MgO	38·18
SiO_2	39·82
H_2O	13·27
	100·14

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[1] (M. F. Conner, Laboratory of Mines Branch.)

ACCESSORY MINERALS IN SERPENTINE.

Besides chromite many minerals of great importance are found, either associated with, or in close proximity to serpentine in this region: and in order to show the importance attached to the study of this class of rocks an idea of their economic value is herewith given: —

The old Huntingdon copper mine, in the township of Bolton, is in the midst of serpentine and serpentinous rocks; the Brompton Lake copper mine, in the township of Orford, is also located in the serpentine. Variegated and vitreous sulphurets of copper, disseminated in small masses in a bed of grey tough serpentine rock, 4 feet in width and flanked by serpentine on each side, occur on lot 28, range ix, Brompton. According to the Crown Land survey, a quartzose chloritic rock, near a band of serpentine, in Orford, contains a small amount of copper pyrites. On lot 9, range A, Orford, and near the junction of the serpentine with a diallagic diorite, six quartz veins occur in the latter rock within a breadth of 25 feet. Some of these are 10″ wide, and they all contain portions of yellow copper ore, which is associated with a greenish serpentine-like material. On lot 22, range i, Garthby, a large mass of iron and copper pyrites is found subordinate to the stratification of the enclosing rock, which is a calcareous serpentine.

Iron ores are also found in many places in the townships, associated with serpentine. A deposit of magnetic ore occurs on lot 2, range x, of Leeds, and also on the west side of Nicolet lake, in serpentine.

In the seigniory of St. Francis Beauce, there is a bed of granular iron ore, 45 feet wide, in serpentine. This ore is composed of common magnetic oxide of iron and ilmenite.

Nickel is seldom or never absent from the serpentine of this area, but rarely forms more than two or three one-thousandth part of the minerals in which it generally appears to be combined as a silicate.

Dr. Sterry Hunt[1] draws attention to the general diffusion of nickel through the magnesian rocks of the Eastern townships. It has, however, never yet been met with in any considerable quantities in these rocks, although workable deposits of its ores may reasonably be looked for in some parts of the formations. On lot 6, range xii, of Orford, millerite (sulphide of nickel) is met with in small grains and crystals, disseminated through a mixture of green chrome-garnet with calc-spar, and also through the adjacent rock. This ore has a brass yellow colour, is soft, and somewhat resembles copper pyrites. It contains 60% of nickel.

The most important mineral found in the Eastern Townships serpentine is chrysotile, generally called asbestos, although the true asbestos is a fibrous tremolite or hornblende. This mineral, which traverses the serpentine in irregular veins, varying in size from mere threads to a thickness of 5″ or 6″, has been treated in a separate monograph by the writer. From the investigations so far made it appears that chrysotile is very seldom found in paying quantities in association with chrome iron ore deposits.

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[1] Geol. of Canada, 1863, p. 738.

Soapstone, which is a more or less compact talc, is found in many places in the townships, and is very often associated with serpentine. When pure and compact this mineral is much used as a refractory material for lining metallurgical furnaces, especially those destined for anthracite. From its softness it is readily cut with knives and saws into the required shape, and is infusible in any ordinary furnace heat.

Among the rocks of the Quebec group, in eastern Canada, argillites suitable for roofing slates occur in many places, and have been successfully worked In the township of Melbourne these slates, which are in contact with dark-green serpentine, make excellent roofing slates.

This serpentine is not only well adapted for interior decorative purposes, but can also be used for the manufacture of small articles, such as chandeliers, inkstands, paper weights, etc., etc.

In France serpentine is used for the manufacture of sulphate of magnesia or epsom salt. The magnesia, which may readily be obtained from this sulphate, makes fine hydraulic cements, particularly well fitted for constructions exposed to the action of sea-water.

CHAPTER II.

THE CHROME IRON ORE DEPOSITS OF CANADA.

Although occurring in many parts of the globe, most of the chrome iron ore deposits contain minerals so impure and undesirable in character; and many are so remote from transportation facilities, that only a few are of commercial importance.

As outlined in a preceding paragraph, the deposits of chrome iron ores are divided into primary and secondary classes. The secondary, or sand deposits, are the natural result of disintegration of the rocks in which chromite occurs, but most of them are of too low grade to be commercially useful. For this reason, only the primary deposits will be dealt with: their manner of occurrence, relation to the containing formation, structure and development, will be described in the present chapter.

Chromite does not occur in Canada in what is generally termed veins, but is found as a rule in irregular masses and pockets, that is, in bodies having no definite form, and no tendency to adhere to dimensions in a special direction. They appear to have no relation to each other. These masses or pockets may have dimensions of from a few feet up to 50 or 75 feet through the larger axis, but they rarely—at least so far as the development in the Canadian mines has demonstrated—exceed 100 feet. Cracks and faults can be found throughout the deposits, but some of the latter appear to possess a more fractured nature than others. Polished and slickensided planes are often met with, and indicate that crushing forces have acted during, or shortly after the deposition of the mineral. Calculations as to the continuation of the deposits towards depth are entirely out of place; because these faults and cracks are very treacherous, and cut off sometimes the whole deposit, and present a barren rock face.

The contacts of the deposits with the serpentine present the most irregular features. Sometimes there is a selvage between the rocks, thus facilitating the extraction of the mineral; at other times both serpentine and chromite are so intermingled, or frozen to each other, that much difficulty is experienced in separating them; these contact rocks, therefore, form a large portion of the low grade ores for the concentrator. In some places there is evidence that the faulting, pointing, and to some extent brecciation of the ore have been greater near the contact of the deposit with the containing formation than farther away from it. This condition is perhaps due to readjustment along the contact shortly after the deposition of the mineral. No well defined walls, which in other deposits would form the deposition line along which the ore can be followed, are noticeable, and the absence of this feature, and of any other leading indication, is the cause for the great uncertainty of chromite deposits. The chromite occurs sometimes in rounded masses of varying proportions, near the contact of the serpentine with the enclosing slate formation. In a general way the irregularities of the chromite deposits may be summed up as follows: the very pockety nature; the apparent non-relation or non-connexion of one pocket of chromite with another; the shooting off of stringers from the main masses of the chromite into the serpentine; the widening and the pinching of the chromite lodes; the intimate mixture of serpentine and chromite—thus producing a great amount of low grade or concentrating ore—and the gradation from the nearly pure masses of chromite through a mixture of chromite and serpentine to the pure serpentine.

As to the indications on the surface of the presence of chromite deposits, it must be said that on account of the great irregularity and variation of occurrence, and the superficial character of many of the outcrops, surface indications present no sufficient data from which to deduce the value of chromite deposits. All outcrops must be explored to depth before any definite idea can be gained as to their extent and quality.

The mining of chromite has always been, and will be attended with considerable uncertainty on account of the very pockety nature of the deposits. These masses or pockets may or may not be connected with one another, and they are limited in extent, so that when a deposit is exhausted, sometimes a great amount of dead work has to be done before another deposit is encountered. It is, therefore, impossible to give any estimate regarding the amount of chromite on a property beyond that which is exposed by actual work done. The fact that a large amount of ore has been taken from a deposit does not necessarily indicate that the same still contains a large amount of ore; if, however, a deposit has been productive of a large yield, this would serve as a strong indication that other larger pockets might be possibly found near by. Yet, in view of the theory advanced for the origin of chromite, if a large deposit is found in an extensive serpentine formation, there is a great probability that other large deposits may be found elsewhere in the area, and in the majority of cases close by.

The surface indications of chromite deposits are of a varied character. Sometimes the serpentine is discoloured and has a ferruginous aspect; it has a kind of dark gossan-like appearance, similar to the outcrops of the nickel copper deposits of Sudbury, which may be from a few inches to several feet thick. Occasionally the solid mineral, with its metallic lustre, can be seen in the solid rock on the surface, and this, it may be said, is the surest sign for the mineral *in situ*.

But we find also loose detritus and solid pieces of the ore in the humus, emanating by erosion, or decomposition from a chromite deposit beneath. It is evident that in the majority of cases these ore fragments, when in appreciable quantities, indicate the presence of a solid deposit; but when they occur on mountain slopes and small ravines, the case may be different. The fragments of ore, or some of them, originally belonging to the deposits underneath, may have been carried away by the action of water, or gradual moving of the soil, and deposited lower than the outcrops from whence they came, and sometimes far away. Thus it happens that we sometimes have an apparently large deposit of chromite in the humus, while we find nothing in the underlying solid rock. In examining a chromite property the inexperienced prospector is deceived by this sporadical occurrence of chromite, and concludes that the property he is examining contains chromite deposits, while really it may contain no chromite *in situ* at all.

PRINCIPAL FEATURES OF CHROME IRON ORE BODIES IN RELATION TO THEIR COMMERCIAL VALUE.

The irregularities of the chromite deposits can be well studied by visiting the various mines which are at present under development. The writer has not found any two deposits in which the conditions resemble one another, in fact all conditions and forms prevail. For this reason it is difficult to fully describe these deposits and to convey a fair conception of their irregularities. In some cases are found so-called crude deposits, that is, lense or pocket shaped depositions containing mostly crude or high grade ore; in other cases, tongue-like apophyses, from a few inches up to 2 feet or more in width, as offshoots from solid ore bodies; again as knolls or kidney-like accumulations distributed through crack fillings in the solid serpentine formation, and also close to the contact of the granitic intrusions; and again in the form of disseminations of the ore through the rock mass.

In the case of the crude ore deposits the ore at the contact with the rock, as a general rule, does not easily separate from the latter; it is frozen to it and requires cobbing by hammer to free it from impurities. Where the formation is highly fissured, as a result of displacement and faulting after its deposition, the ore itself shows fine cracks and fissures, and sometimes highly polished surfaces, admitting easy spalling. In a few isolated cases some of the ore lenses—as at the Montreal mine exhibit distinct demarcation lines on the contact and the ore separates readily from the serpentine, while in most deposits a gradual transition from pure ore to the disseminated ore, and pure serpentine, is observed. These latter occurrences furnish the bulk of the milling ore in all the mines; they are less desirable from a mining point of view, since it involves the handling of a large quantity of rock, depending upon the percentage of chromite therein, in order to obtain the pure article. However, it must be mentioned that this variety forms in several cases the backbone of the chromite mines, and in view of the most uncertain and irregular occurrence of the crude ore, it is doubtful whether a chromite mine could be made profitable without the exploitation of these disseminated ore bodies.

In the disseminated form chromite occurs as scattered grains, the size of a pea and smaller, through the serpentine. It occurs very often in proximity to solid crude ore bodies, and in this condition, as outlined above, forms the transition product from crude to the pure rock. It often ap-

PLATE I

Pocket of Chrome Ore, Montreal Mine of the Black Lake Chrome and Asbestos Co.

pears in cracks and fissures in the serpentine formation, and can be noticed frequently in the vicinity of granitic dikes, in conjunction with the pure ore.

As to the shape of these disseminated ore bodies, it must be stated that, in some mines a banded arrangement can be noticed, while at others, lense shaped, pockety accumulations are the principal features. The outcrops of this low grade, disseminated ore are of peculiar appearance, the grains have a brownish tarnish, the serpentine in some cases becomes rust coloured, while in others, especially in the softer varieties, white or grey colour predominates; however, in all cases the outcrops of the disseminated ore are easily discernable, and no difficulty is experienced in their location.

It has been often asserted that chromite deposits, in order to be commercially useful, must lie along the contact of the serpentine with the quartzose schist and slate formation, or near the diabasic or dioritic dikes. This may be applied to one or two instances in the district, but the writer has not found it a general rule; in fact some of the larger deposits are far away from the contact, just as excellent asbestos deposits are found to occur in the centre of the serpentine formation. At Montreal the productive chrome bearing formation is quite a distance from the contact, while in the vicinity of the large disseminated ore body on lot No. 26 B, Coleraine, on the high ridge overlooking Black lake, no contact can be noticed. Quite a number of instances can be given here, where apparently economic deposits occur away from the contact, and the experienced prospector, knowing this, will look for outcrops all over the latter, as well as along the contact.

Most of the serpentine in the chrome iron ore region contains a very small percentage of chromite, disseminated through the mass in an exceedingly fine state of division. Samples of the rock were granulated for the purpose of determining whether there could be any chromite extracted but it was found that in some of them no grains or specks could be detected with the naked eye. These samples were then analysed for chromite, and it was found that they contained from 0·73 to 6·32%.

A fibrous hornblende which sometimes occurs in cracks and fissures through the chrome iron ore region, was subjected to the same test, and although quite a number of samples showed only traces of the mineral, still in a few localities chromite was found to be present to the extent of 6·42%, even in parts of the formations which were quite distant from economic deposits.

GRANITIC DIKES.

The serpentine is often cut by dikes of granite, which, as they fill cracks in the formation, are thus of younger origin than the surrounding rock. They range in size from small bands of 1 and 2 feet up to large intrusions of 50 and 100 feet in width, and some of the grey and reddish varieties form conspicuous hills between the village of Thetford and Black lake.

Very often these intrusive dikes can be noticed in or close to chrome iron ore deposits, exerting as they do quite a favourable influence upon the deposition of the mineral. These dikes cut the serpentine in almost any direction; their dip is mostly vertical, but in several cases nearly horizontal beddings may be observed, as in the big pit of the Montreal mine. Here a narrow dike of decomposed granite, varying in width from 12″ to 18″, dips under an angle of about 15 degrees. It is cut through and dislocated at several places, over a length of about 20 feet, and is accompanied by stringers and small accumulations of chrome iron ore (Fig. 2). Evidently this dike was originally vertical, but through subsequent faulting and shifting of the formation was dislocated and tilted. Another dike which is worthy of notice is the one occurring in the deep pit near Caribou lake, belonging to the Black Lake Chrome & Asbestos Co. This granitic dike strikes N.W. 74°, and dips 60° to the horizontal; its width is from 25 to 30 feet. On both sides considerable accumulations of excellent chrome iron ore occur, thinning gradually out, and becoming the disseminated variety farther away from the dike.

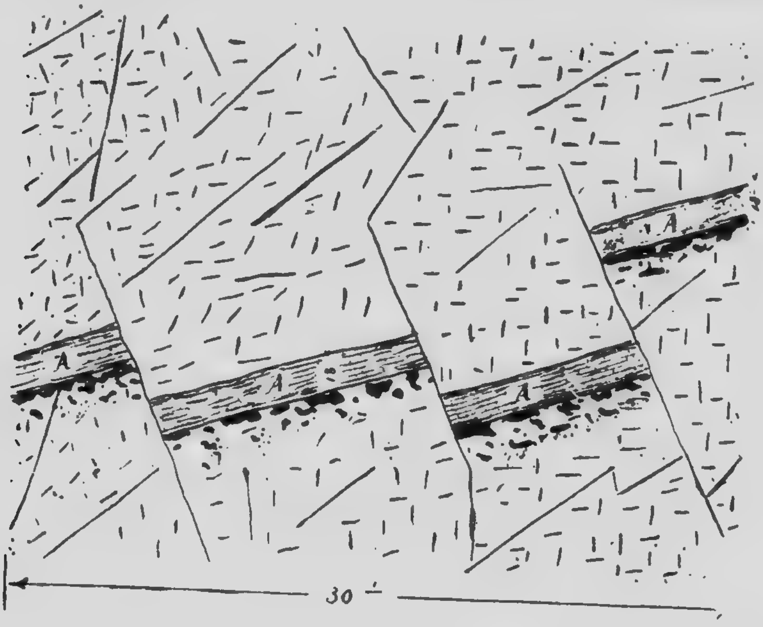


Fig. 2—Section View of Granitic Dike, (*a*) (Kaolinized) 18″ wide displaced by faults over a length of 30 feet, accompanied by chromite.

In many cases intrusions have scattered and altered the rock in contact. The latter appears to be highly fissured, and at places large accumulations of chrome iron ore can be noticed, apparently indicating that the intrusion of these dikes has exercised some influence in this direction. Sometimes these dikes cut off the work entirely, and very often a face of good chrome iron ore; but in the majority of cases good ground is generally found by driving through the dike mass.

A characteristic feature of a great many of the granitic dikes met with in the chrome iron ore region is the kaolinization of the feldspar in the granite, which imparts to the latter a great softness, causing it to crumble away when exposed to the air; when freshly mined the dike rock appears to some extent spongy and contains a fair percentage of water. In the Montreal pit of the Black Lake Chrome and Asbestos Co. a small dike 14″ wide was noticed, which contained kidney-like fragments of chrome iron ore; evidently during the injection of the magmatic rock substance fragments of the chromite already formed close to the fissure were trapped and embedded in the solidifying granitic mass. (Fig. 3). Another feature of the granitic dikes in the Montreal pit worthy of attention is the peculiar colour which some of them exhibit. Small dikes had a distinct pink colour, and samples of the dike granite analysed showed traces of chromium and manganese. However, as chromium with alkali (of the feldspar) gives a distinct purple colour, it is fair to assume that the purple colour of the kaolinized granite is simply due to the presence of chromium.

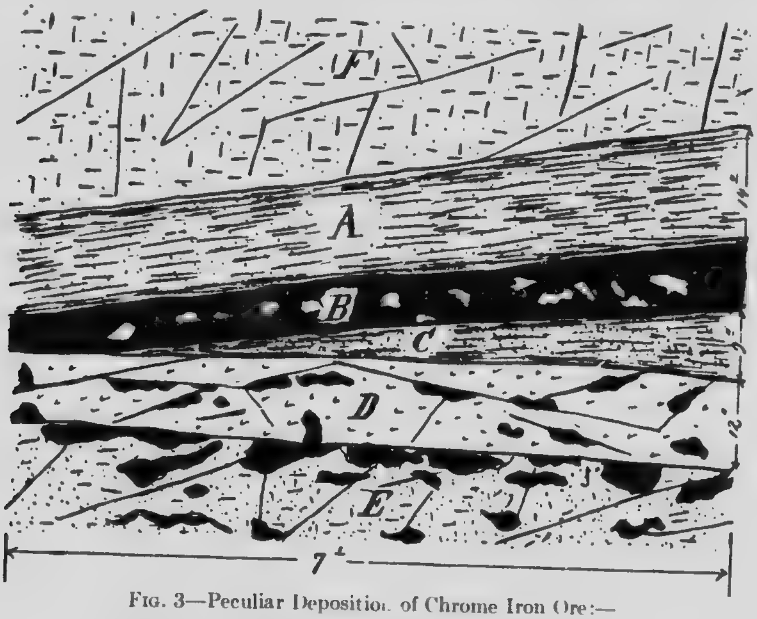


Fig. 3—Peculiar Deposition of Chrome Iron Ore:—

(*a*) Granitic dike 14″ wide. (*b*) Chromite (containing fragments of granitic dike). (*c*) Kaolinized granite of purple colour. (*d*) Slickensided Serpentine and Kidneys of Chromite. (*e*) Chromite in ordinary Serpentine. (*f*) Ordinary Serpentine.

Percentage of Chromite in the Rock.

From the foregoing paragraphs it is quite evident that there is a considerable variation in the quality of the ore and rock mined. While one mine may deliver a very high percentage of crude, another may not be able to produce any crude at all, but a milling material rich in chromite. In the one case the crude forms perhaps from 20 to as high as 50 per cent of the total rock mined, while the bulk of the poorer rock goes to the mill. In cases where the crude deposits are not large and the disseminated ore predominates, from 5 to 10 per cent of crude only may be obtained, while all the balance of the ore, with the exception of unproductive chutes, is treated in the mill.

The quality of the milling ore varies from day to day in every mine, unless special precautions are taken to mine only a certain chute of ore of known quality. It is evident that the mill has to depend upon the mine for a regular supply of ore, and any changes in the conditions of the latter are felt at once in the mill. As far as experience has shown, the lowest percentage of milling rock of the total rock mined is 20 per cent, the highest 65 per cent.

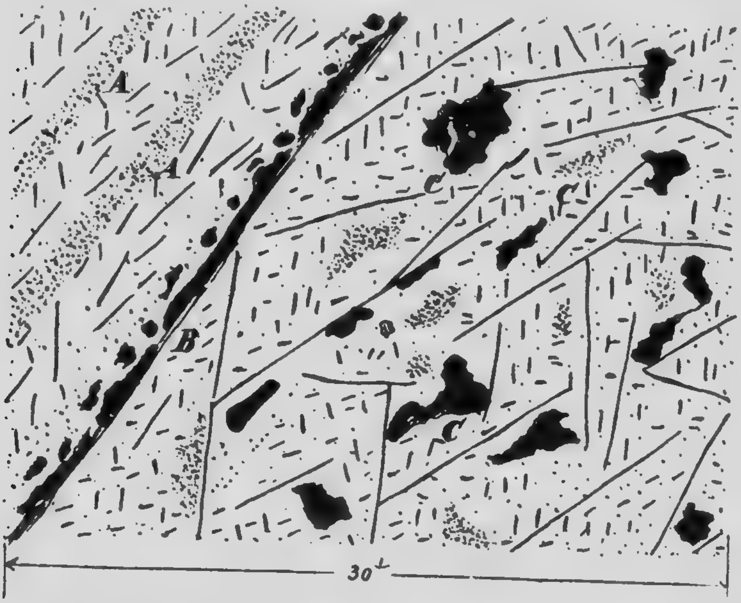


FIG. 4—Section View Through Serpentine Formation, showing:—

(*a*) Banded accumulations of disseminated ore. (*b*) Chromite accompanying slickenside. (*c*) Chromite pockets and disseminated ore.

On an average the chromite in the low grade milling rock, as at present furnished by the mines, may be taken as from 40 to 60 per cent.

Rock containing less than 10 per cent chromic oxide, as a general rule is not put through the mill, and is allowed to go to waste.

PLATE II

Diamond Drilling at the Montreal Mine

CHAPTER III.

MINING OF CHROME IRON ORE.

At present chrome iron ore is mined according to two methods, first by underground, and second by open-cast work. As to the first method, it may be said that the difficulties incident to severe winter seasons, such as are experienced in Canada, are overcome by sinking a shaft and running drifts along the ore bodies, as is being done by the Black Lake Chrome and Asbestos Co. Here a large body of crude ore, measuring in width from 5 to 40 feet, is exploited by a shaft 6 × 10 feet inside timbers, the inclination being 60 degrees to the east. This shaft is at present 300 feet deep, and sinking is being continued. Cross-cuts at 250 and 340 feet depth will eventually tap the ore bodies, which through a system of upraises will subsequently be prepared for stoping.

Previous to sinking this shaft, however, the Company had resorted to open-cast work; the ore bodies, which at the surface appeared as lenticular deposits, were exploited by an open-cut, approximately 100 feet long and 40 feet wide, to a depth of about 70 feet. From this point the ore was followed to a depth of 250 feet, when it was decided, on account of the dangerous condition of the works, to close down, and commence the new shaft, which was located at a distance of about 50 feet from the old workings.

As to the advantages and disadvantages of both the underground and open-cast methods in the exploitation of chrome iron ore deposits, it may be said that, in order to decide which method is best suited in a given case, it is necessary to distinguish between large crude and disseminated ore deposits, because advantages gained in one method may be offset or lost by the impossibility of reaching or exploiting properly the ore bodies, or by the difficulties incident to the severe winter season as experienced in Canada. In the case of extensive ore bodies which yield a large percentage of crude, the writer believes that the underground method of development is the only way of dealing with the exploitation of these deposits; above all, this method has the great advantage of avoiding the exposure of the men to the inclemency of the weather, which interferes with the proper execution of the work, reducing, therefore, its effect, or forcing the suspension of the work in case of bad weather such as heavy rain, snow or extreme cold. It also reduces the quantity of waste rock to a minimum, which in some cases may be left underground for filling up the stopes, thus saving the heavy additional expense caused by hoisting and disposing of the dump on the surface.

The case, however, is different with disseminated ore bodies, and it is questionable whether the advantages derived from underground work are not offset by the inconvenience of reaching all the ore contained in a certain area, and the loss of excellent milling rock, entailed by the necessity of leaving large pillars for the purpose of safety.

The advantages of open-cast work compared with underground work may be summarized as follows: -

(1) Easier supervision.

(2) No trouble as regards ventilation, the men always working in good air.

(3) Easier layout of work in larger steps and stopes than is usually possible in underground works.

(4) No timbering is necessary.

(5) Complete extraction of all the chrome iron ore encountered in the rock. No loss in form of pillars.

In the case of open-cast work a great difficulty arises in the way of the selection of a suitable dumping ground, and although this difficulty seems to be trivial with small operators, it may assume an acute form as soon as the work is conducted on a large scale. This will be even more apparent in the case of mines which have little ground at their disposal, and it will be necessary to secure dumping ground elsewhere, if it cannot be obtained close to the mine.

OPEN-CAST WORK.

The first process in opening a quarry is the removal of the soil, which covers most of the chromite bearing areas, varying in thickness from a few feet up to 25 feet. In Black lake the crest and the slope of the large serpentine ridge is for the greater part covered with a thin layer of humus, thus rendering prospecting work comparatively easy, while in the lower ground of this locality the territory between Black lake and Thetford is covered to a considerable depth with soil. Close to Thetford, the thickness of the overlying soil is in some places 15 or 20 feet. The removal of this soil for open quarry work is performed only in the summer; the winter being too severe, on account of frost and snow, for this class of work.

As a general rule the soil is cleared off with pick and shovel, and carried away in dumping carts, but in large operations the employment of a steam shovel is recommended, as this method is much cheaper and quicker. With a small steam shovel from 100 to 125 cubic yards can be removed per shift, only three men being necessary.

Most of the quarries met with by the writer have a very irregular shape: they follow the trend of the chromite bearing zones, while the lean serpentine, or intrusive dikes, are left as pillars. However, in two instances where the locations of the chromite bearing and lean rock, and the location and extent of the intrusive dikes have been more fully studied, the quarries have a more regular outline. Here,no discrimination is being made between dikes,lean rocks, or rich portions of the serpentine. No pillars of any rock have been left. for the reason that these only would prevent mining with advantage towards depth. The shape of these quarries is rectangular, and although the outlines of the walls are not strictly in conformity with this shape, the execution and the progress of the work in the pits indicate a certain system which has latterly been followed. The main advantage of this system lies in the fact that, generally a number of different zones, both lean and carrying chromite, are thus laid open; and the work, together with the supply of the ore, can be regulated to suit requirements.

As a general rule, in the larger pits the rock is taken down in a series of benches, stopes, and terraces, which vary in dimensions according to the size of the pit.

EXPLOSIVES.

The great bulk of the dynamite used in the chrome iron ore mines contains 40% nitro-glycerine. The cartridges, as a rule, are 8″ long × 1¼″ in diameter, and are packed in boxes of 50 lbs., containing from 85 to 95 sticks. The price is from 18 to 20 cents per pound.

EFFECT AND COST OF HAND DRILLING.

Hand drilling is still in use in the smaller mines and prospects, and also for block-holing. As a rule three men are employed, with 1″ octagon steel, and 6 and 7 pound hammers.

The average capacity in hard serpentine or granite is from 15 to 18 feet per shift, and the cost per foot, including explosives, from 25 cents to 30 cents. In some of the mines, block-holing is done by one man only, using ¾″ steel, and a 3 to 4 lbs. short handled hammer. The capacity is from 7 to 9 feet per day, and the cost, including explosives, about 22 cents per foot.

EFFECT AND COST OF MACHINE DRILLING.

In nearly all the mines machine drilling is in vogue for the breaking of the rock *in situ*. The proper placing of the bore-holes is a very important factor in obtaining the best results for blasting in chrome ironstone. To do this it is necessary that the operator has a thorough knowledge of the position of the strata, and the position and trend of cracks and fissures. To obtain this knowledge the intelligent miner examines the rock attentively, carefully allowing for each blast the position of any joints and fissures in the rock to enable him to form a judgment as to the proper direction to be given to the bore-hole, and the free sides available for the best results; but it happens too often that two miners will have different opinions as to the proper charge for a certain shot. The result, frequently, is a waste of explosives, which sometimes assumes considerable proportions.

Where the rock is massive and the walls of the benches to be taken down vertical, the direction of the holes is vertical, or nearly so, and where the rock is much fissured, the holes have generally an inclined position according to the largest fissures, and the bulk of the rock to be taken down.

When blasting benches with several free sides, the bore-holes are arranged in rows, and they are as nearly as possible parallel with the longest free side, in order to obtain the deepest bore-hole, and thus be able to use relatively, the smallest quantity of explosive material. In order that the charge may be as fully utilized as possible, due regard is given to the contour of the free sides, and the longest line of resistance. The bore-holes in the case are generally made vertical, so that the explosion will not have to lift the rock it breaks down, but will allow it to fall by itself, and give less work afterwards in removing.

The depth of the holes ranges from 8 to 10 feet, and in the case of exceptionally large faces 12 to 15 feet. The charges of the holes vary of course, according to the position of the holes, the quality and quantity of rock, as above outlined; but as a general rule, in the course of ordinary work, and where the faces are free on one side, from 0·45 to 0·5 pounds of dynamite are used for every foot drilled.

The rock drills in use are mostly of the Ingersoll and Rand types, with 3⅛" cylinder and a stroke of 6¾".

For block-holing little giant drills are used. The diameter of piston is only 1⅞", and the length of the stroke 3⅜", the depth of the holes drilled being from 1 to 2 feet.

The steel usually employed is octagonal in shape, 1⅛" in diameter for the larger, and ⅝" for the smaller drills. In drilling, a short steel bar called the starter is first used, and when this has drilled as deep as it will reach, a longer piece is substituted for it; this is followed by a still longer piece, and the process is continued until the desired depth of the hole is reached.

The diameter of the hole at the beginning, made by the starter, is for the larger machine 2⅜", which is gradually reduced by using successively steel bars of smaller diameter, to 1⅛" at a depth of 10 feet. As a rule, two sets of steel bars are provided for each machine, so that one set may be sharpened while the other is being used. The price per pound of steel is at present from 7 to 9 cents.

The motive power for actuating rock drills is usually compressed air, or steam; but in the employment of the latter there is a large loss from condensation in transmitting steam from the boilers to the drills. In the usually severe winter, all the main pipes require to be covered with insulating material, which entails extra cost.

Compressed air has a great advantage over steam; the loss in transmission is small, and consequently the effect in drilling is comparatively high. The effect with steam drills is from 40 to 45 feet per shift of ten hours. The total cost per foot, including power, labour, and explosives, at present prices of fuel, is from 17 to 18 cents, not including, however, wear and tear of machinery and interest on capital involved.

In nearly all the mines the firing of shots is performed by means of electric batteries. There are a few instances where one hole blasts are still in vogue.

The expense for explosives per ton of rock broken in mines, where the same is of a solid massive character, is about 3½ cents per ton; in mines where the rock is much fissured and shattered, the cost is a little less.

As an average, each pound of dynamite exploded brings down from 4·25 to 5 tons of rock.

SEPARATION AND REMOVAL OF ROCK AND ORE.

After the firing of shots, the broken material undergoes a hand sorting process, which is different in every mine, according to the grades to be produced and the ground worked. Where much crude is produced, the bigger pieces are spalled with a sledge hammer, and the ore and cobbing material is sent to the cobbing shed, while the refuse and the disseminated ore is sent for treatment to the mill. The crude ore is then sorted, and all that will probably run over 40 per cent of chromic oxide is put aside. This product is then again divided into three grades. All ore containing more than 48 per cent of chromic oxide is designated as N. 1, and all from 40 per cent to 48 per cent is put aside as N. 1, 2, or 3, according to quality. All the refuse from the cobbing shed is sent to the mill.

If the bottom of the quarry is on the same level as the top of the dump, the removal of the material is simple. The latter is loaded directly into dumping cars, or on platforms subsequently placed, by means of a small derrick, on trucks, and then delivered to its destination; but in most cases where deep mining is going on, heavy boom and cable derricks are employed.

Boom derricks are employed in only a few of the smaller mines, or where dumps have to be worked over again. Quarries of large dimensions do not admit of the successful general application of boom derricks, on account of their limited working radius.

CONSTRUCTION OF CABLE DERRICKS.

A cable, stretched from the top of a well guyed frame or mast to some point across the working pit along which the load is to be transferred, constitutes the main feature upon which the cable-derrick is constructed. A carrier suspended from the cable by a system of pulleys travels along the cable, and may be arrested, lowered to pick up the load, and rehoisted at any point between the limits of the cable. In this manner the load is transported along the cable.

The cables may span a distance of 400 feet, hence are made of crucible steel, and have a diameter of from 1½″ to 2″, depending on the length of the span and load to be carried. The ropes used for hoisting are from ⅝″ to ¾″ diameter.

The cable-ways may be either inclined (Fig. 5) or horizontal (Fig. 6). In the case of the inclined cable-ways the carrier is provided usually with one rope—the fall rope—which, however, also serves as a hauling rope. To prevent the carrier moving along the cable when the load is raised, it is necessary that the angle of inclination of the cable be at least 30°, to render the component of the force of gravity on the load acting down the cable of sufficient intensity to retain the carriage in position until the load arrives at the stop on the cable.

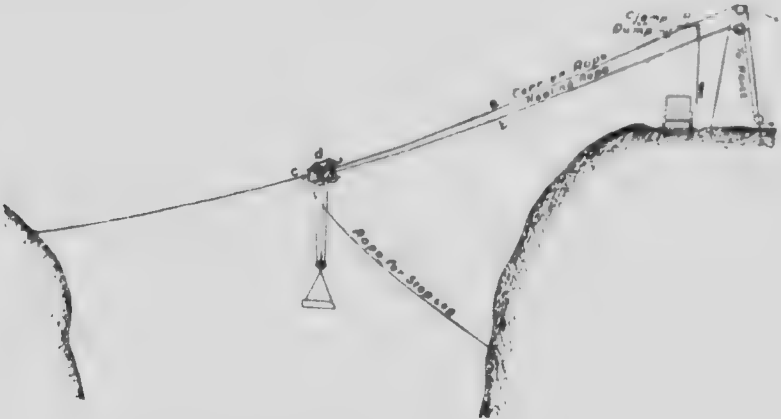


FIG. 5 – Incline Cable Hoisting Plant.

On stopping the carriage at any point on its upward journey, the load may be lowered and dumped, after which the carriage returns down the incline to the stop. It is generally necessary, however, to provide a bridle or link (e), pivoted to a wooden clamp on the carrier rope over the dumping point, which link is raised by a cord (f), and dropped over the hook on the end of the carriage before dumping, and afterwards released to allow the carriage to return.

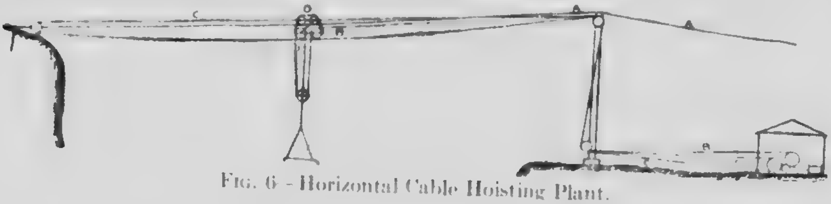


FIG. 6 – Horizontal Cable Hoisting Plant.

To obtain control of the carriage, so that a load may be picked up or lowered at any point on the line without shifting the stops on the carrier rope, a third rope or extra hauling or tail rope, ⅜″ diameter, is required, which is attached to the carriage, and wound in at the same speed as the fall rope after the load has been lifted; by means of which the carriage may be restrained in its movement down the incline on the return trip, or made to stop over any point in its range of travel, for loading or unloading purposes.

By making the hauling rope endless, that is, by passing it from the carriage around a separate winding drum on the hoist, and around a sheave on the farthest end of the cable-way, the latter may be used in a horizontal instead of inclined position. In some mines the inclined, and in others the horizontal cable-ways with tail rope, are employed. Miners claim in general an advantage for the horizontal over the inclined cable-way, on account of the ease with which the carriage may be stopped at any desired point from the hoist, while with the inclined cable-way a setting of the stopping log on the cable rope is necessary.

The support for the cable consists either of a pyramid made of four legs, fitted and bolted securely, or of two legs held in vertical position by ⅝" guy ropes, constructed in the manner illustrated in Plate III. On the top of these supports are placed also the sheaves for the carrier and haul rope. It is claimed for the pyramid shaped supports that they are more solid and stronger, and do not require any guy ropes, while the two leg supports are of simpler construction and can be more easily removed.

The cable carriage (Fig. 7) is substantially made of wrought iron, and is comparatively light. The running wheels are of cast iron, have flanges and are provided, as a rule, with antifriction bearings. The hoisting wheels are also of cast iron, and have a diameter of from 18" to 24" in order to reduce the wear on the hoisting rope and to enable the gin block to lower as freely as possible.

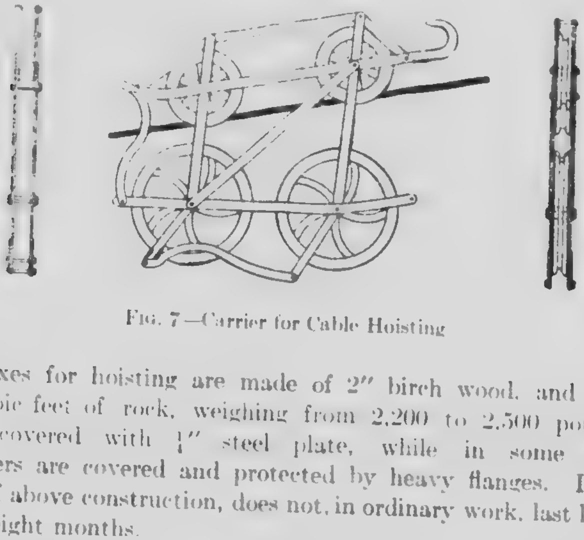


FIG. 7—Carrier for Cable Hoisting

The boxes for hoisting are made of 2" birch wood, and hold from 16 to 20 cubic feet of rock, weighing from 2,200 to 2,500 pounds. The bottom is covered with ¼" steel plate, while in some mines the outside corners are covered and protected by heavy flanges. It is stated that a box of above construction, does not, in ordinary work, last longer than from six to eight months.

The heavy cable is fastened at both ends, either to a system of heavy wooden legs loaded with stones, or to a large iron bar securely fastened in a drill hole in the solid rock.

All hoisting engines used for the operation of cable derricks are of the double cylinder type, with reversible friction drums. The newest type of cable-way engine is the so-called special cable-way hoist as manufactured by the Jenckes Machine Co., Sherbrooke, Que. This hoist has friction drums, all mounted on one axle, with brakes worked by hand lever and link motion: the narrow and curved drum serving for the endless tail rope.

EFFICIENCY OF HOISTING PLANT.

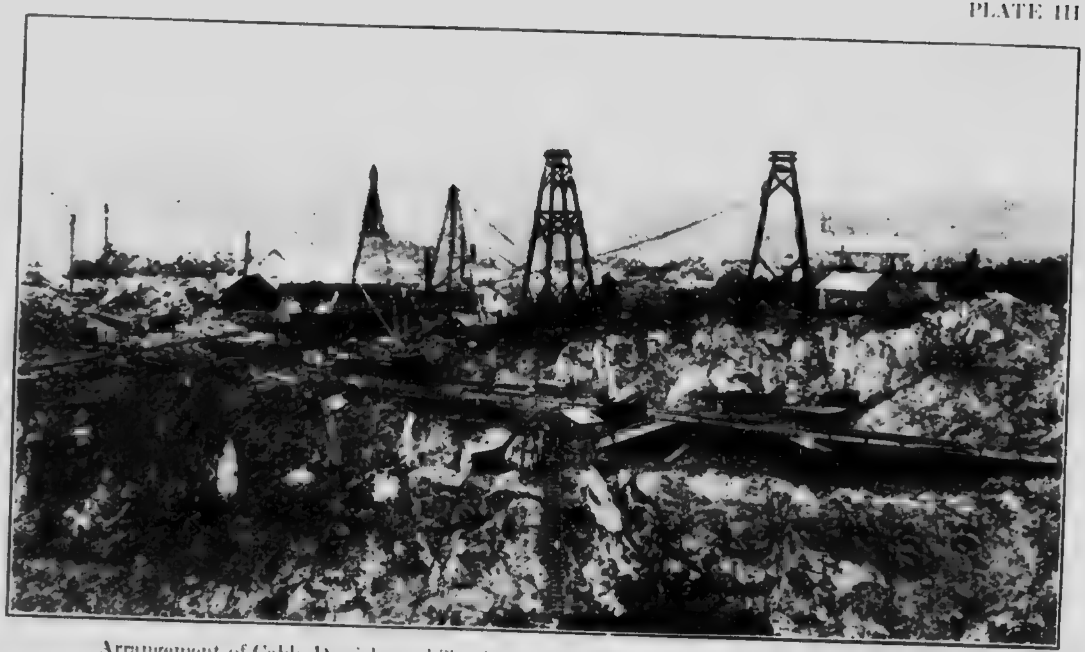
The number of tons of rock which can be raised from a quarry by means of a cable derrick depends upon the depth of the pit, the distance to be hauled, and the capacity of the machinery. As a rule, the distance in the quarries ranges between 200 and 300 feet, while the greatest depth so far attained is 50 feet. Taking these figures as a basis, and assuming the load to be one ton, and the capacity of the hoist 40 h.p., on an average from 300 to 350 tons of ore can be raised in a ten hour shift. It must be understood, however, that a cable derrick is used also for other purposes: lifting and shifting heavy pieces of rock in the quarry in order to clear the working face after blasting. On account of the work entailed through the separation of the useful from the dead material in the bottom of the pit, a cable derrick can very seldom be used to its full capacity. As a general rule, for a supply of 100 tons of milling rock daily, one cable derrick is required. For the delivery of every further 75 tons of rock one additional derrick is needed, so that for, say 300 tons, 5 cable derricks must be installed. The number seems large, and a smaller number might do, but the initial advantage thus gained is more than offset by the loss of valuable crude ore, caused by superficial work and lack of care in the proper separation of the materials.

HAULAGE.

The dumping cars in use consist of a truck and a moveable box, constructed for a gauge of 26″, holding from one-half to one ton of dump.

No dumping cars hauled by mechanical power have yet been introduced into chrome iron ore mining, but they are at present largely employed in the asbestos mines in the district. These box cars hold from 3 to 6 tons of rock: they are furnished with brakes and such mechanism as will permit the tilting of the box to both sides of the track. The gauge of the latter is 42″. In the asbestos mines haulage is being done by small 10 and 12 ton locomotives, and it is claimed that not only has the cost of transport per ton been reduced considerably, but that accidents are very few. Some of the locomotives are of the Gearing type: an innovation by Mr. George Smith, the general manager of the Bell Asbestos Co. The main advantage of these Gearing locomotives is the great ease with which very sharp curves are turned; while their general construction is such as to reduce repairs to a minimum. It is claimed that in some of the asbestos mines such locomotives make from 50 to 60 miles a day. The diameter of the cylinders is 8″, and the stroke 10″. The engine is fitted with steel frame, a saddle tank, and steam brake. For the mining and treatment of several hundred tons of chrome ironstone this power haulage system is indispensable; as the cost of haulage can be reduced to a very low figure.

PLATE III



Arrangement of Cable Derricks and Tracks near Border of Pit   King Bros.' Mine, Thetford

Position of Cable-Derricks and Tracks.

The position of the cable-derricks is determined by the location and number of working points in the pit, and changes with the shifting of operations. Where the quarry is of rectangular shape, all the supports and hoisting engines must be placed on one side of the pit; the former usually all in one row near the border of the pit, leaving, however, enough space for the passage of dumping cars. A good illustration of this arrangement is the large quarry of King Brothers, at Thetford (Plate III). The derricks employed are all of the tail rope type, the cables being stretched nearly parallel, at fixed intervals over the pit, while all the hoists, some of them grouped together in one building, are stationed back of the supports.

In cases where the pits have an irregular shape and curved outline, an effort should be made to place the hoists and supports on one central spot, from whence all the cable-ways are operated.

The tracks for the haulage of dumping cars are generally laid alongside and close to the borders of the quarries. In the case of cable-derricks, it is a good rule to have two parallel tracks close to each other, one for the loaded and the other for the empty cars.

In order to control the output of a mine, each engineer stationed at a hoisting engine marks the number of box loads he has hoisted during the shift, and the summary report of all the hoisting engineers must tally with the number of cars delivered at different stations—that is at the cobbing shed, the mill, and the dumping ground.

Compressed Air.

The most economic motive power for actuating rock-drills and hoists is compressed air, supplied by straight line or duplex air compressors. In order to secure uniformity of pressure, and to get rid of the water and impurities, the air is conveyed from the compressor into a receiver, which is generally supplied with a safety valve, and pressure gauge, also with a cock for letting off the water, which collects gradually. Where the distance from the pit to the air compressor is very long, say over 500 feet, a second receiver should be installed about half way, for the purpose above indicated. The capacity of an air compressor is generally given in the number of rock drills it can supply. The pressure usually produced for air drills is between 80 and 90 pounds.

The straight line air compressors have the great disadvantage of consuming much steam. They are superseded now by the Duplex Steam Compound Air Compressor manufactured by the Rand Drill Company, and constructed on more economical lines.

Drainage.

Siphons are sometimes used for drainage where the quarries are shallow and located on the slope of a hill. As a rule the serpentine rock does not carry much water; most of the latter comes from the surface and is collected at the deepest point in a sump. A duplex pump of small size may be stationed at some point of the quarry well protected against shots, and this will suffice to keep the water in the sump under control by being operated only a few hours a day.

CHAPTER IV.

THE DRESSING OF CHROMITE FOR THE MARKET.

Under the term dressing is generally understood the process by which the miner converts his mineral into a saleable article, or by which he extracts a marketable product from it. This process in the case of chromite is divided into, (1) hand cobbing, (2) mechanical dressing. When the chromite is coarsely mined with the gangue, it is feasible to separate it, to a considerable extent, by means of hand sorting. This process is generally practised as a part of the mining of the ore, in which high grade ore may sometimes be broken out of the lode separately. If pure chromite be broken, a portion of it will be converted into fines, and the percentage of these fines depends upon the brittleness of the ore, the size to which it is broken, and the method of breaking. In washing with water a good deal of these fines will escape settling, no matter how perfect the process of washing, and the high contents of useful mineral found in the tailings generally tell the tale. It is, therefore, of great importance to avoid breaking more than is necessary.

The process of hand sorting is divided into two operations, (1) breaking of the ore, and (2) hand picking. The former may be done by a jaw crusher or, manually with the aid of a hammer. As a rule, the breaking of an ore by a jaw crusher produces an excessive quantity of fines, which is not desirable for hand sorting, and generally the breaking with the hammer is much preferred. The size, of course, to which the ore has to be broken in order to make hand sorting very efficient, depends upon the general character of the ore, and no rule can be laid down, as the condition in which the ore is found varies in every mine.

After the ore is broken, either by machine or with the aid of a hammer, it may be passed over a screen, or a grizzly, to remove the fines, which are sent to the mill for future treatment; the remaining pieces of ore may then be sorted either by men or boys. The success of hand sorting is largely dependent upon the manner in which the ore is presented to the sorters. In large establishments the sorters sit at large stationary tables on which they draw the ore to be sorted from heaps or pockets. An efficient method is to discharge the ore on a circular, slowly revolving table, around which the sorters stand; or, the ore may be discharged on a travelling belt from which the sorters can select it.

A revolving picking table, as manufactured by the Allis Chalmers Company, of Chicago, is illustrated by Fig. 8. The broken ore is placed on a table by a chute, and the spreading out of the ore is facilitated by the revolution of the table, until meeting an inclined stationary scraper, when it is swept off into a chute, which delivers it into cars, or to a continuous conveyer, to transport it to the next operation. Boys, stationed around the table, pick out the mineral from the slowly moving layer of ore. The table is made of punched iron or steel plate. Experience has shown that it is easiest for the pickers to throw the sorted material in front of them; and this arrangement is easily made with tables of annular form: in connexion with which a conical surface having radial partitions, may be arranged inside the ring, around the vertical axis, in order to facilitate the separation of different classes of ore, which will slide down the cone into proper receptacles.

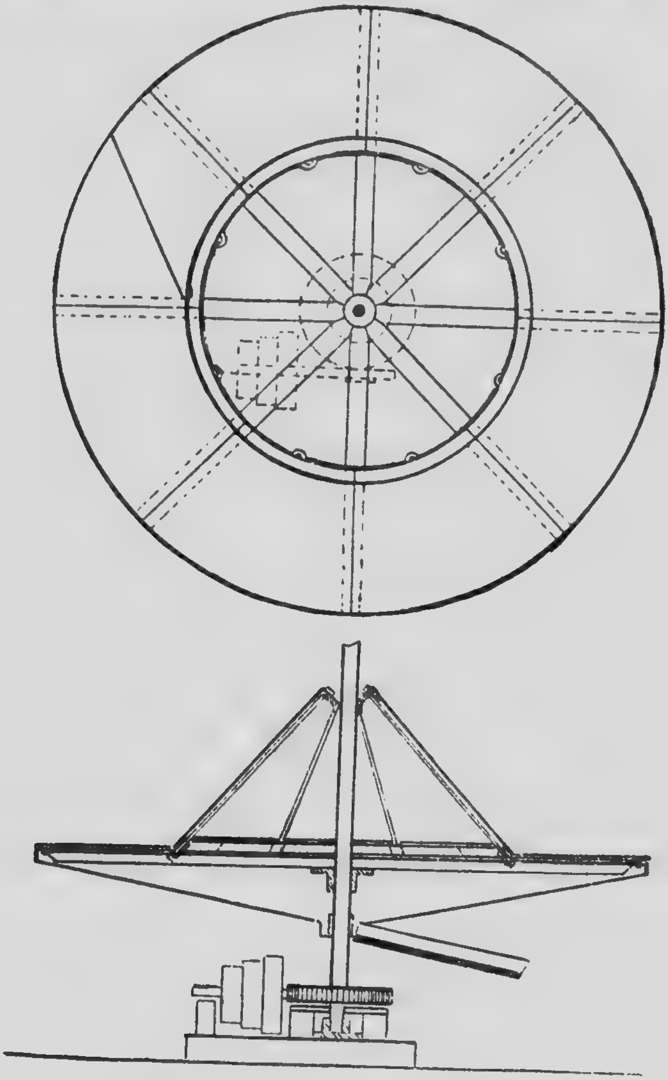


FIG. 8—Revolving Ore-picking Table.

The endless belt tables are so well known that they require no special description, beyond the statement that, they can be made use of in the mills between the crushing machinery. The Robins Belt Conveying Company makes a special picking belt, which is used in a number of mills. It is heavy—32″ to 36″ in width, and is supported on idlers; which are so shaped as to give the belt a broad flat surface at the centre, with slightly raised sides. It is made to travel at speeds varying from 30 to 60 feet per minute. Owing to its elasticity the belt will withstand spalling of the ore directly upon its surface. The advantage of rubber belts over any other make, lies in the fact that, there are no links to wear, and no crevices wherein pieces of ore can jam.

In order to secure the maximum efficiency in hand sorting, it is necessary to have adequate light, careful supervision, and arrangements which serve to increase the convenience of the pickers. One point is very essential: the layer of ore must be put on the table in such a way that every piece can be noticed, and that every part of the material is within reach of the sorters.

In Europe, in all the metalliferous mines, culling is carried on to a degree of skilful subdivision which would not be reached in modern Canadian practice. Under ordinary conditions culling would be a step in the milling process. All the ore from the mine, having been broken by a crusher to the size determined for the next machine, would pass over a grizzly, from which the coarse material would go to the picking table, and the rejected stuff from the latter to the next crushing machinery.

MECHANICAL SEPARATION.

History.

The first test with Canadian low grade chromite ores for the purpose of concentration, was made by Mr. J. Obalski, the Quebec government engineer, 1897, in the factory of Edward P. Allis Co., Milwaukee, U.S.A. A new concentrator—the Castelnau table—was employed. This apparatus consists of an endless rubber sheet, inclined laterally, onto which the ore is fed at one end. In moving with the belt the ore meets a water sheet, which, owing to the lateral slope, removes the lighter parts, the pure ore only being carried to the other end by a strong current of water. The special plant erected by the above firm consisted of a Blake crusher, crushing rolls, a Bayley grinder, and a Castelnau table, as described above. The ore was crushed in the grinder to 35 mesh; later on, a Chilian mill was used, and the ore reduced to 18 mesh, fine. The tests were made in quantities of two tons of poor chromite ore. Nine parcels of ore were run through the mill, and with the exception of two tests, all the experiments were satisfactory. The highest concentrations were from 28·68 per cent to 45·70 per cent chromite, and from 37·24 to 56·28 per cent chromite.

It must be mentioned, however, that in all these tests the tailings were not re-treated, and for this reason the concentration of all the ores treated is not so high as was anticipated. Mr. Obalski succeeded, however, in demonstrating that the proper concentration of low grade ores would offer an opportunity to operate low grade deposits; thus prolonging the life of a mine, and adding to its revenue in no small degree.

Realizing the advantage of utilizing these low grade ores, the Coleraine Mining Co., in 1898, erected a mill on the shore of Black lake, about two miles from Black Lake station, on the road to Coleraine. No tables for concentration, such as those employed in the tests at Milwaukee, were used, but concentration jigs were installed. This mill consisted, in the main, of two Blake crushers, the first of which was followed by a table for hand sorting, the crushers reducing the dimensions of the pieces to 2½″ and then to 1″. These pieces then passed between crushing rolls, which made 175 revolutions per minute. The pulverized ore passed through a revolving perforated cylinder; the oversize went to the jigs, consisting of three compartments, and making on an average about 150 pulsations per minute, with an average drop of 2 inches. Water for washing was supplied from the lake by means of a pumping station. A 75 h.p. steam engine furnished power for the whole mill. Towards the end of 1898 the mill was set in operation, but a number of changes and additions had to be made in order to prevent the loss of a good deal of ore in the tailings. Accurate results of these milling operations have never been reported, but it was known that the mill did not give the satisfaction anticipated.

In 1901, Mr. Whitney, manager of the American Chrome Company, for the first time erected a concentration mill, consisting of stamps, on lot 9, range xiii. From the very start it gave fair results, and all chromite mills which have been built since, follow in a greater or less degree the system of separation as laid down by Mr. Whitney. The mill consisted of a Blake crusher, 2 crushing rolls, a battery of 5 stamps, and a Wilfley table with the usual accessories. It turned out about 20 tons of concentrates per week. In 1903 some improvements were made, another battery of 5 stamps and 2 more Wilfley tables were added, making in all 10 stamps and 3 tables. On an average 18 tons of milling rock were treated in 10 hours, yielding from 4 to 5 tons of concentrates.

The present system of refining chromite is the result of the cumulative experience of several mill men, extending over a period of 10 years, which has naturally evolved a system of separation conforming to the peculiar conditions in which the ore is found. The wet treatment, with the aid of stamps, is found to be best suited to Canadian chromite. Further improvements are still being made, but they are much more likely to originate in the district itself than outside of it.

MACHINERY USED IN CHROMITE MILLS.

Before entering upon a general description and detailed account of the method attempted in the mechanical separation of chromite, it is necessary in order to fully understand the working principles, to describe the different classes of apparatus which, according to experience, have given satisfactory results. The machinery usually employed in the mills does not differ materially from that employed in the mechanical separation of other ores, but its operation and adjustment require special attention.

JAW-BREAKERS.

The first crusher through which the rock has to pass is invariably a jaw crusher of large size. This is a machine for reducing rock preparatory to fine crushing by rolls. It is durable and easy to operate. The rock is crushed between jaws, one stationary, the other swinging, and driven by a powerful toggle movement.

The adjustment of the jaws, and the size of the rock leaving the crusher, are determined by the character of the apparatus used in subsequent treatment. One rock crusher alone may be used to prepare the rock for the stamps; but for a larger capacity it is preferable to use two sizes with a screen between, the second crusher relieving the subsequent apparatus of a great deal of work.

Since the large size and irregularity of the feed rock generally does not admit of automatic feeding, the jaw breakers are fed by hand and shovel; in many cases by a chute, sloping from the bottom of a bin, the attendant pulling forward the ore in the shute by rake or pick.

The jaw breakers may be divided into two types, according to the movement of the jaws: (1) those which are pivotted above, giving the lower part of the jaw the greatest movement; (2) those which are pivotted below, giving the upper part of the jaw the greatest movement. To the former class belong the Blake crushers; to the latter the Dodge crusher.

The movement of the lower part of the jaw is greatest in the Blake crusher, and the result is that a product of various sizes must drop from the machine, whereas in the Dodge crusher the movement is greater at the top of the jaw, the lower part remaining nearly stationary, hence the product leaving the machine must be of nearly uniform size: determined by the distance the jaws are set apart. This explains the higher capacity of the Blake, while the Dodge crusher delivers more fines, and a more uniform product.

ROTARY AND GYRATORY CRUSHERS.

These crushers may also be employed in stamp mills, preparatory to feeding the ore to the stamps, but as their working principle is so well known, or can so easily be studied in the catalogues of the manufacturers of this class of machinery, a description of them is unnecessary.

STAMPS.

These are machines f [illegible]erizing ore by means of weights, imitating the action of a spalling hammer. The stamp mill is not, as experience has shown, an ideal pulverizer, as its defects are great; it turns out the ore or pulp in grains of all sizes, from an impalpable powder up to the size of the mesh employed. With all its defects it holds its own among the numerous inventions for the purpose, and for this reason its use is widespread.

The most highly developed mill used in the concentration of chrome iron ores, is the so called California stamp-mill (Fig. 9). This mill consists of a mortar, A, standing upon a mortar block, B. The stamps, C, are lifted by cams, D, keyed to a camshaft, E, and drop into the mortar. A strong frame supports the camshaft and the driving gear. As a general rule, five stamps drop to a single mortar, forming with all accessories one unit, or a battery.

The tappets, F, form cast iron cylinders, having a central bore of the diameter of the stem, G. The shoes, F, are generally made of cast steel. A more detailed description of stamp mills will be found in any text-book dealing with mining machinery, and only a few details will be given here with regard to their adjustment to the treatment of chrome iron ores:

(1) *Mortar.*—This is constructed of cast iron, weighing from 6,000 to 7,000 lbs.

(2) *Screens.* The screens employed are usually brass wire screens; their meshes range from 20 to 25 per square inch.

(3) *Stamps.* -The weight of the stamps in use is from 1,000 to 1,100 lbs; the number of drops per minute is from 90 to 95; the lift is from 7 to 9 inches, according to the wearing of the dies on an average 10 inches.

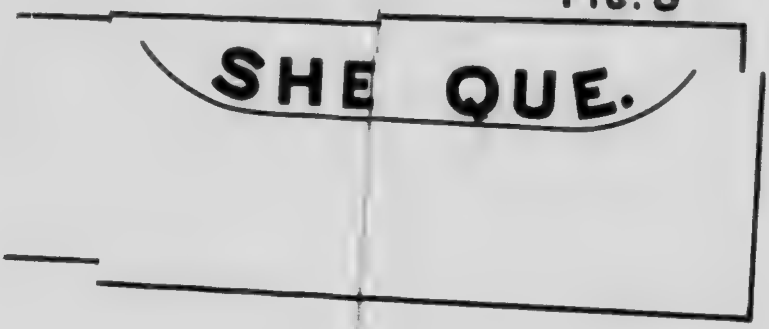
(4) The capacity of the stamps is from 1·75 to 2·50 tons of chrome iron ore per double shift.

The most serious imperfection of stamps -and it may be said of all pulverizing machines- is that, after crushing the ore to the requisite size, they keep on pulverizing it to the state of the finest slimes; the mortar is generally filled with a sufficient quantity of water to keep the whole of its contents in motion. At each blow a quantity of fine material is produced, and this, instead of being carried away immediately, is drawn by suction caused by the raising of the stamp, back to the bottom of the mortar. In this way the material is again crushed and pulverized, although it is already in a sufficiently fine state. This action continues indefinitely, so that the pulp issuing from the screens contains mineral in all degrees of fineness: from that of an impalpable powder up to the size of the mesh of the screen. It will be seen from this that the pulp will eventually contain a very large percentage of fines, as has been determined by a number of experiments: more than 50% being less than $\frac{1}{100}$ of an inch in diameter.

The mortar boxes carry two screens, one in front and one behind; for the purpose of avoiding choking of the mortar box and breaking of the screens.

These very fine slimes of chrome ore are very difficult to treat in a stream of water, and the consequence is that, in the present mill practice there is quite a loss of concentrates on that account.

Fig. 9



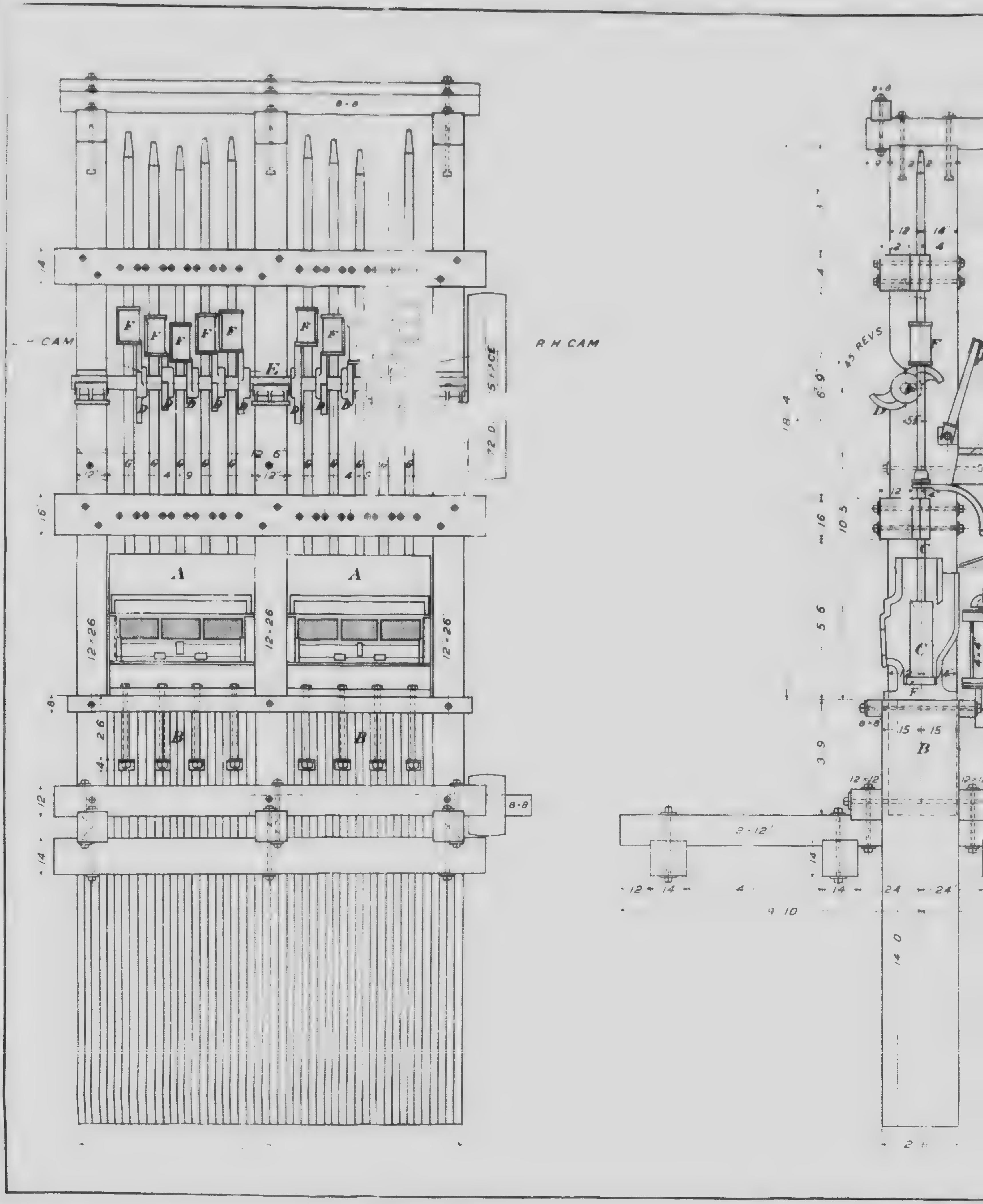

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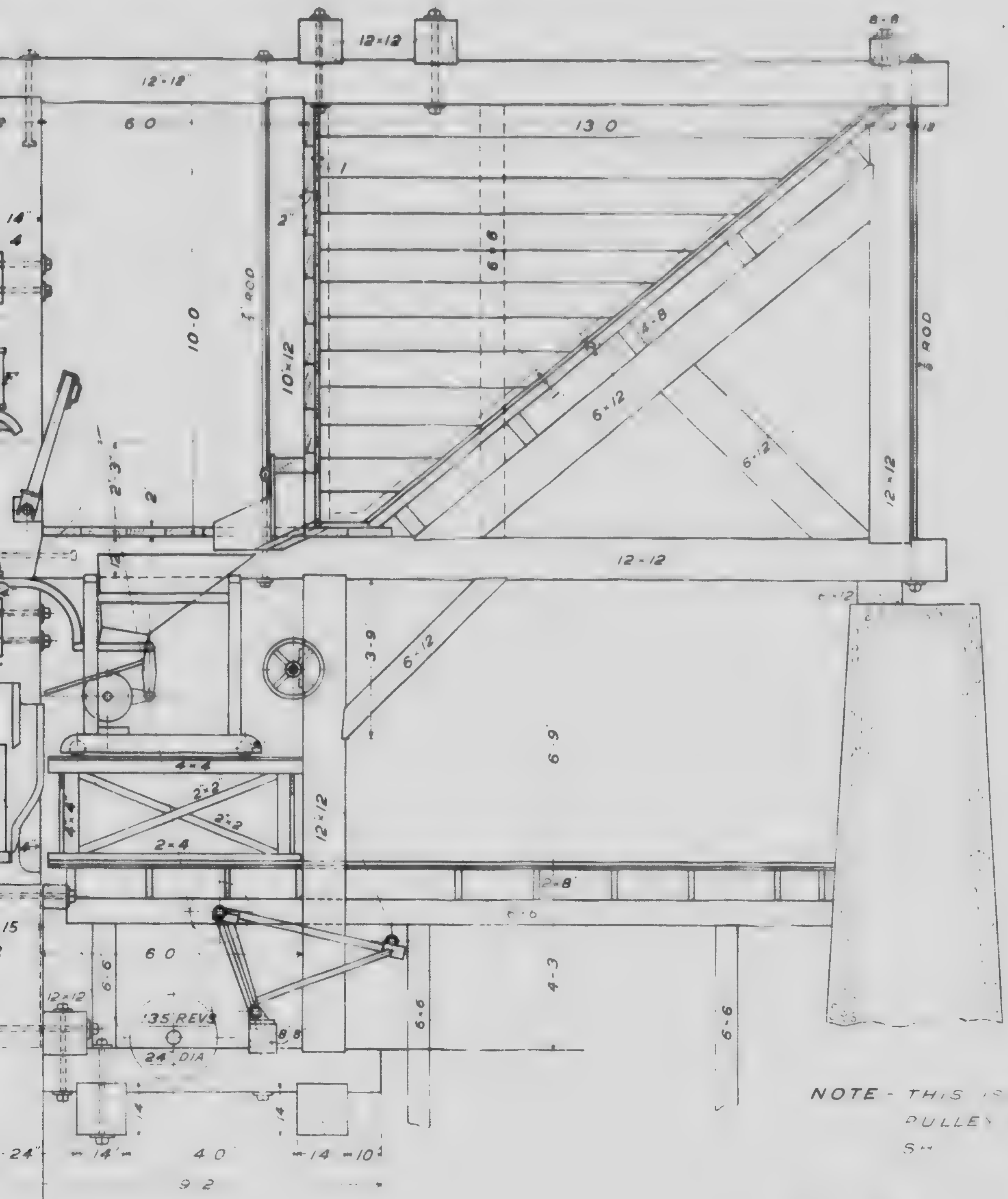
FIG. 9



NOTE - THIS IS DRAWN WITH CHANGING PULLEY AT OTHER END OF CAM SH[illegible]ES [illegible] R.H

THE JEN[illegible] MACHINE CO.

GENERAL ARRANGEMENT OF

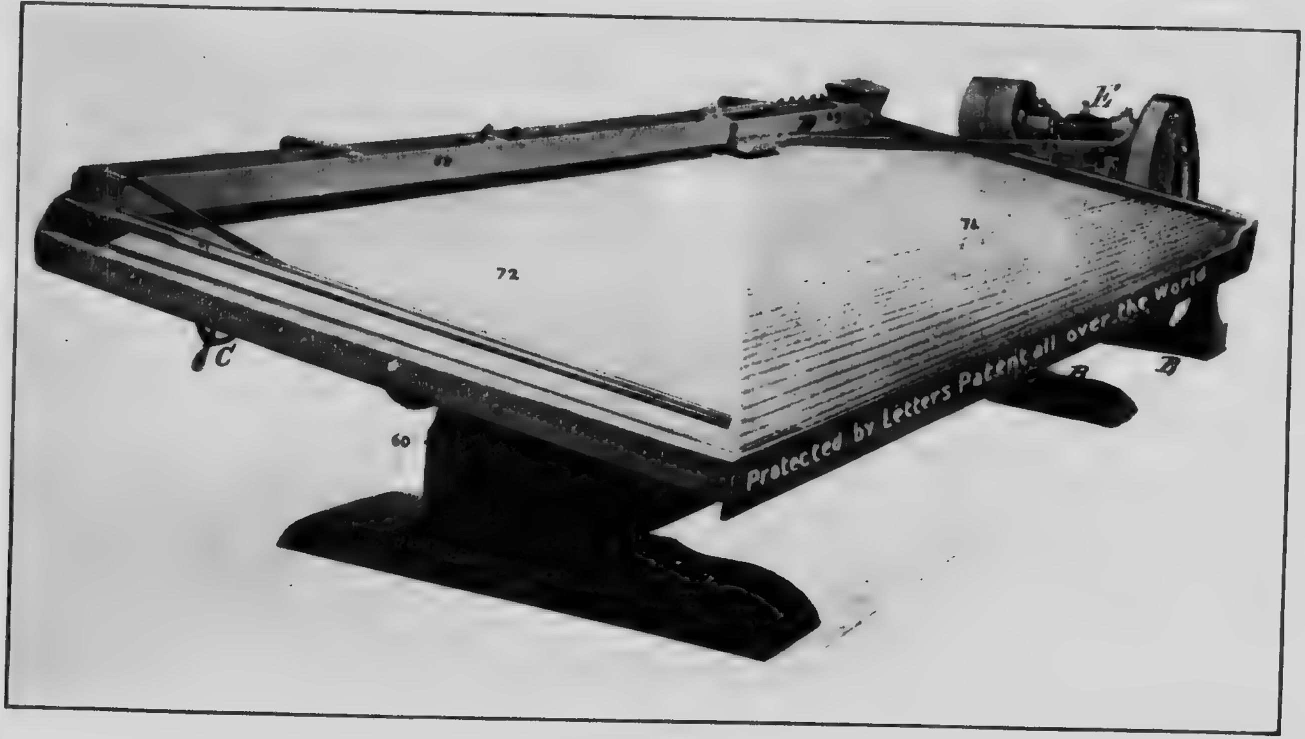
STANDARD 10 STAMP BATTERY

SCALE 3/8" = 1'-0 DATE JAN. 21 '04

SHERBROOKE QUE.

These very [illegible] stream of water, and the consequence is that, in the present mill practice there is quite a loss of concentrates on that account.

PLATE IV.



Wilfley Table.

THE WILFLEY TABLE.

This table has now been in use for a number of years in the concentration of chrome iron ores, and has given satisfaction.

It is built on a heavy wooden girder, A, (Plate IV), resting on three cross pieces or feet, B. On the top of this girder are cast iron cross beams, arranged for adjusting the slope of the table by means of beams and screws operated by a hand wheel, C, at the side. The table proper is of extra strong construction; the longitudinal ribs are made of hardwood encased in sheet steel, and the top boards are placed diagonally, and securely fastened to the ribs. The top surface is covered with linoleum and upon this is laid a series of riffles, ending along a diagonal line, and forming a combination of riffled portion and plain surface, as shown in the plate. The pulp is fed upon the table through a series of holes in the upper side, on the pulp box, D. This pulp box is attached to the sideboard of the deck, as it is found that the motion of the table ensures an even and proper distribution of the feed. The wash water on the table is delivered along the upper side by an open box of special construction, which distributes it in a thin stream and completely prevents currents on the table surface.

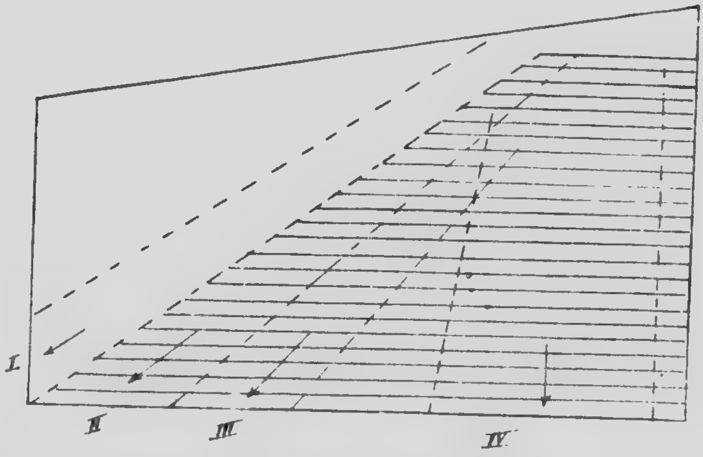


FIG. 10—Division of Products on Wilfley Table.
(I) Concentrates (II) Middlings (III) Tailings (IV) Slimes.

The table receives a shaking motion by means of a powerful toggle movement, E, placed near the feed end; it makes as a general rule from 215 to 240 pulsations per minute. The values are caught by the riffles, and carried to the end by the shaking motion, while the lighter particles, or tailings, are carried across the riffles by the motion of the water and discharged at the side.

The usual division of products upon a Wilfley table is easily and naturally made as shown on Fig. 10: I being concentrates, II middlings, III tailings, and IV slimes. Of these, the concentrates, I, are nearly clean chromite, only a slight quantity of small grains of serpentine being present. The middlings, II, carry some large and some small grains of chromite. The tailings, III, carry some very small grains, and the slimes, IV, carry very minute grains of chromite.

All these products discharge into launders, placed conveniently at the sides of the table.

As a general rule the middlings, which carry still an appreciable percentage of chromite, are treated again in the same manner on a second table.

The concentrates from the first tables run from 50 to 55 per cent; the re-treating of the middlings on a second table produces concentrates carrying from 44 to 48 per cent chromic oxide.

The capacity of a Wilfley table in double shift is from 12·5 to 15 tons, crushed to 20 mesh; the power consumed 1 h.p., and the washwater used from 150 to 300 gallons per hour.

Accessories for Mills.

Among the many accessories for mills may be mentioned the following specially important ones:

(1) *Ore bins.*—The varying production of ore in the mines calls for receiving bins large enough to serve for storage, when the mine is producing more ore than the mill can treat, and to provide ore for the mill when none is being received. It often happens that mining and milling are carried on for 24 hours, while hoisting and shipping cover only 12 hours. A common rule for the construction of bins is, that they shall hold at least 24 hours production of the mine, and they are often much larger. Intermediate bins are used in some mills to act as reservoirs, so that a temporary stoppage of one part of the mill will not necessitate the stoppage of the operations preceding and following.

(2) *Feeders.* In taking the rock from the ore bins to the stamps,the supply is regulated; but it often happens that a sudden rush of ore will choke them, and unless they are supplied with an extra amount of power and strength, which is generally not the case, they will break. To avoid this trouble feeders are used, which are kept constantly full of material, fed to the apparatus by automatic machinery mostly by oscillating or revolving gates.

(3.) *Conveyers.* The conveyers in use are either of the bucket, or scraper type. The former are generally employed for lifting the rock to the ore crusher or bins. They consist of a series of steel buckets hung on trunnions between two parallel link belts. The scraper conveyers are used for the transport of the concentrator from the tables to the store room. They consist mostly of sheet iron blades attached to an endless chain and moving in an ordinary launder.

Summary of Operations in the Separation of Chromite.

The present mill practice for the treatment of chromite, after a number of experiments covering a period of ten years, constitutes a process, which to a certain degree conforms to the peculiarities of the different classes of ore found in the district; but improvements and innovations of a character not yet clearly foreseen, may be introduced. The wet method has been found to be the most convenient; because water separation disintegrates the earthy and clayey matter, freeing the particles which have been cemented together by the clay, and releasing them for individual treatment. The ordinary dry method, which consists principally in drying the ore, crushing, grinding, and screening it, and subsequently treating it by air jigs, effects neither of those results. A further advantage of the wet method—and this is very important—lies in the fact that,no drying of the ore before it is pulverized is necessary, the run of mine being subjected at once to the crushing operation after it leaves the pit. Again, the concentrates need not be dry for shipment; as a rule they are simply drained after leaving the tables and contain a certain amount of moisture when shipped. All this means a saving in the running expenses of a mill, and may in the treatment of a large tonnage run into high figures.

As mentioned in a previous chapter, some of the ore mined is rich enough to be shipped directly to the consumers, and this ore, as a general rule, carries over 50 per cent of chromic oxide. No ore is being concentrated which runs over 48 per cent; in fact little ore is sent to the mill which carries more than 45 per cent, because such ore finds a ready market at satisfactory prices.

The purpose in the concentration of all lean ores is, therefore, the raising of the percentage of chromic oxide to 45, and any concentration less than this is not considered satisfactory.

In the present method of treatment there are unavoidable losses in the tailings; but it may be said that, compared with those incurred in the separation of similar ores by the wet method, they are not extraordinary. The practice of separation consists, in all the mills, of crushing in a Blake crusher, grinding by stamps to 20 mesh, and passing the pulp over Wilfley tables. Three grades are made: heads, middlings, and waste. The middlings are treated again in an extra Wilfley table, producing heads and tailings. The former still contain a great quantity of waste rock, and are treated again in the mill, while the tailings run sometimes as high as 10 per cent of chromic oxide. As a general rule, for every 10 stamps two tables are in use, and for every 4 tables one separate table for the treatment of the middlings.

In the present practice the tables receive the pulp coming directly from the stamps, in sizes from the finest slimes up to the coarsest grains, passing a 20 or 25 mesh screen. The work expected from the tables is natural sizing of this pulp, but as the ore consists of two separate minerals of different specific gravities, the work of sorting is expected as well. In other words, we expect from the Wilfley table two mechanical operations entirely different in their fundamental principles, namely, sorting and sizing. This overloading of the table is the principal cause of the loss in the tailings, which in the present mill practice may be put at from 3 to 9 per cent. However, the present practice of treating chrome iron ore has the great advantage of simplicity, and compared with the treatment of other metalliferous ores, of low cost. In order to make the system more effective, and devoid of any unnecessary waste, without detracting from its great advantages, it has been suggested that the ore should be sorted before it is dealt with on the tables, and this operation is generally performed in classifiers.

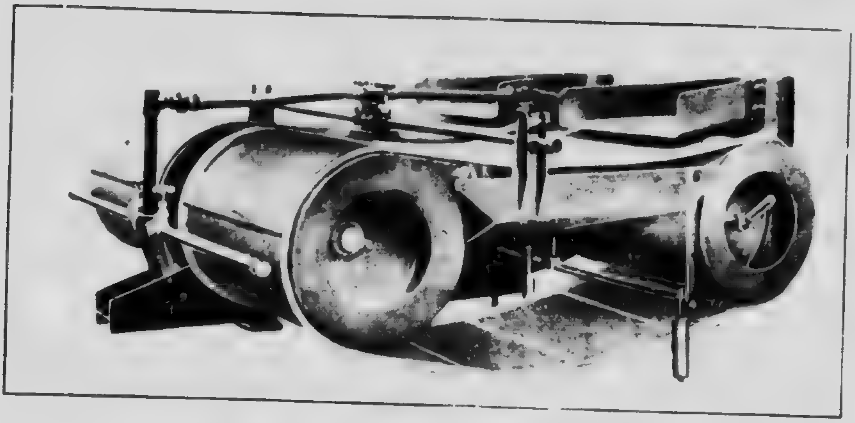
THE CALLOW SCREEN.

The principal part of this apparatus is a travelling belt, or belt screen cloth, which receives the pulp from distributing aprons or feed soles. The belt is set in motion by head and tail rollers, and travels continuously in a horizontal direction, at a speed varying between 25 and 125 feet per minute according to the character and quantity of the ore. The operation of the pulp distributing aprons or soles forms a very important part in the successful application of the whole apparatus, because a preliminary sorting and sizing is effected through these contrivances. The grains of the ore, which are of all sizes, fall from the aprons on the screen,the coarsest and largest strike the latter at a point ahead of the smaller ones, and naturally a space is left on the screen between the two. The pores of the cloth in the rear being, therefore, still uncovered and open, permit the free passage of the fines and water. Simultaneously with this action the cloth is moved forward, and the deposit of oversize is continuously and unintermittently removed from the separating or screening zone, and thus the machine continues to perform its function so long as it is kept moving and is supplied with feed.

After leaving the screening zone, the deposit of oversize is carried forward, and passes under a shaking spray of clear water, where any remaining traces of slime, or of fine adhering particles, are washed, and pass through with the water from the spray into the undersize hopper beneath. Continuing, the oversize still clinging to the screen cloth passes in front of a small impinging spray, which is conveniently situated somewhere about the mid-diameter of the front roller, and the oversize is there washed off the screen cloth into the oversize hopper below.

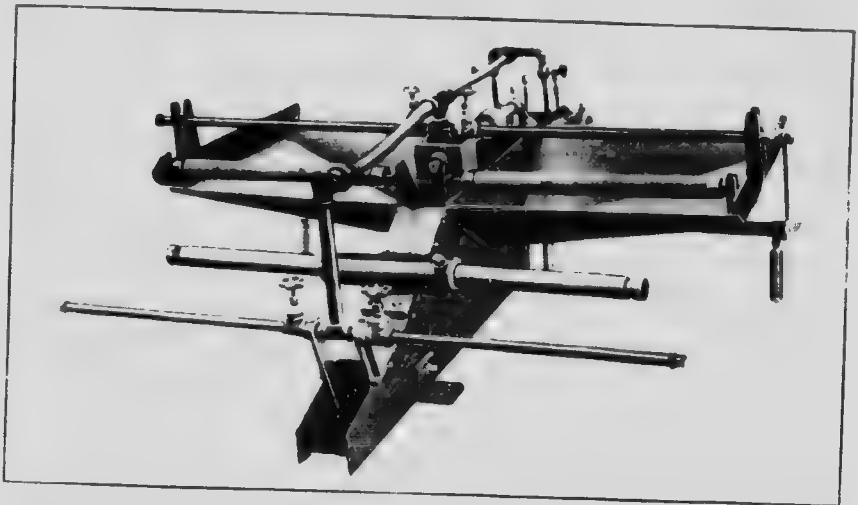
The apparatus is in two parts, each half being the duplicate of the other. The two belts are independent of one another, but operate from a common driving mechanism. The speed of the belts can be varied by means of cone pulleys, and the driving shafts are arranged so that either side can be thrown in or out by suitable frictional contact, adjusted to each driving roller.

PLATE V.



24" Duplex Wrought Steel Callow Screen. As manufactured by the Utah Mining and Machinery Supply Co., Salt Lake City, Utah, U.S.A.

PLATE VI.



24" Duplex Wrought Steel Callow Screen "Uncovered". (As manufactured by the Utah Mining and Machinery Supply Co., Salt Lake City, Utah, U.S.A.)

HORIZONTAL REVOLVING SIZING SIEVE.

The apparatus constructed by the author, and used with success in the sizing of graphite grains and flakes in the year 1896, is worked in a similar manner to the Callow screen, and would probably give satisfaction in the sizing of chromic oxide pulp. It has a diameter of from 2′-6″ to 3′ 0″, is of convex shape, and revolves round a vertical spindle. It consists of brass wire cloth, or better of perforated galvanized iron, the mesh of which is determined by the size of the product treated. The construction of this apparatus may be seen from Fig. 11: B is the spigot pipe of a launder A, discharging the pulp on the sieve C, revolving in the manner indicated round a vertical spindle D; E is a spray pipe for conveying the flakes into a launder F.

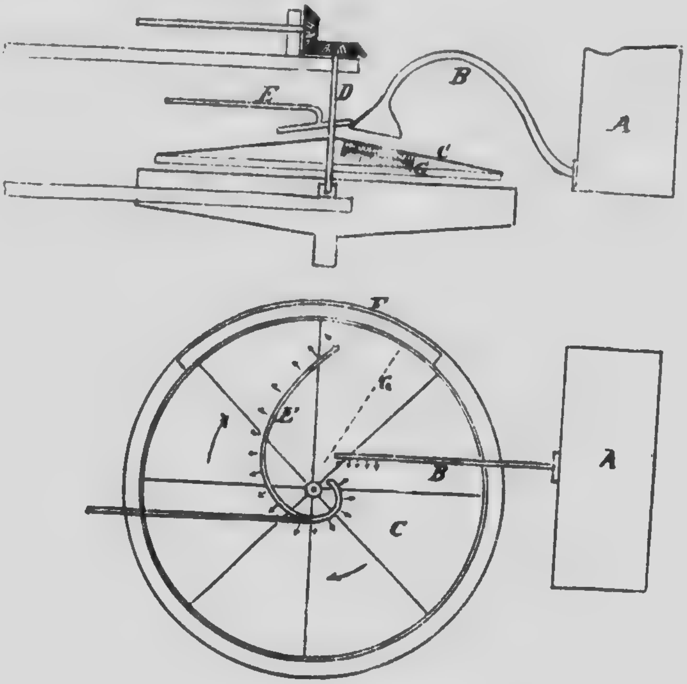


FIG. 11—Horizontal Revolving Sizing Sieve.

The action of the sieve is as follows:

The pulp entering by B spreads out over the sieve, and by the revolution of the table is carried before the fine water sprays of the pipe E. The smaller particles pass through the sieve in a launder underneath, while the concentrates, consisting mostly of the larger flakes, are swept before the fine water sprays into the launder F on the periphery of the sieve. In order to prevent the clogging of the latter, a revolving brush, G, is placed under the sieve in the manner indicated, which cleans the holes from clogging material, after they have passed the water sprays. The sieve makes from four to six revolutions per minute, depending upon the quantity and size of the grains

POWER AND WATER USED.

The horse-power required per ton of ore treated varies, of course, in the different mills with the quantity and kind of rock treated; and it will even vary in the same mill owing to slight changes of velocity; speed of feeding and discharge, and size of the material fed to the breakers. For these reasons average figures cannot be applied to every individual mill, and they can therefore, be of general value only.

Most of the mills inspected have a sufficient reserve capacity to obviate the necessity of forcing any of the machinery, and to permit the temporary suspension of a machine for adjustment and repairs.

As a general rule, and for ordinary circumstances, the following power for the different apparatus in a 20 stamp mill is used: –

One Blake rock breaker, No. 2	12	h.p.
4 ore feeders.	2	"
20 stamps, 1,100 lbs., 90 drops	30	"
5 Wilfley tables	5	"
Conveyers and friction	10	"
Centrifugal pump delivering 100 gals. per minute.	2·5	"
Total horse-power required	61·5	h.p.

As a general rule, this mill treats on an average 40 tons of ore per day. Every ton of rock requires approximately 1·5 horse-power; so that a mill of 50 stamps treating about 100 tons of rock requires 150 horse-power.

Most of the mills are now run by electricity, the great drawback at present in the operation of steam engines in the district being the lack of fuel. The St. Francis Hydraulic Power Company has built a power station at the rapids of the St. Francis river, about 6 miles from Black lake, and is supplying a number of mines with electric power; while the Shawenegan Water and Power Co., which has its power station 90 miles distant, is distributing electric power to almost all the mines at Thetford, and Black Lake.

The main advantages of the use of electricity are that, electric motors require less attention and repairs than steam engines, and are at the same time more efficient in transforming electricity into work than steam engines are in transforming the calorific power of steam into work. The loss in transmission is less with electricity, and it may be said that wherever electricity has been applied to mill work it has been found very successful.

In regard to the division of power in the mills for different motors to drive different parts of the machinery the economical advantage which electricity affords in this respect in machine shops, namely, the running of individual machines which are operated intermittently with a separate motor, does not exist in the mills under consideration, since the milling plants run continuously.

As to the water used in the mill, the greater the quantity the more rapid will be the action of the stamps and the less the sliming, because as soon as the rock particles have been reduced to a certain size they will be discharged by the large quantity of water into the mortar box. On the other hand, if too little water is used, the rock particles are exposed longer to the crushing action than is necessary, and consequently the amount of fines will be excessive. Again, if the amount is too small, the crushing of the next fragments is seriously hindered by the very fine ore which has not been discharged, and consequently the resulting pulp will contain an excessive amount of fines and coarse particles, and no medium sizes. All these conditions cause a very incomplete separation of the ore from the gangue; especially in mills where the pulp is not sorted before entering the slime tables.

As a general rule, the amount of water used in a 20 stamp mill, such as described on pages 60 and 61, is disposed of as follows: –

For each stamp 75 gals. per hour; for 20 stamps, per hour....	1,500	gals.
For each Wilfley table 300 gallons per hour; for five tables....	1,500	"
Total amount of water used per hour..................	3,000	"

Cost of Labour in Mills.

The cost of labour in mills varies as much as the power necessary to run them. While some mills are laid out and constructed so that little attendance is necessary, others may be cramped for room: the machinery employed not being easily accessible and the general mechanism such as to require extra help to watch it. If exact figures were at hand they would show that the number of tons treated per man varies greatly, even in mills of practically the same construction. This variation depends upon the following factors:

(1) The difference exercised in the care with which the concentrates and tailings are produced.

(2) The size of the plant, since a large mill can always be run with less labour than a small one.

(3) The favourable location and design of the mill to minimize labour costs.

In the absence of accurate data of all the mills in the district, the writer has chosen the following example of a 20 stamp mill, which has a good plant and is working under ordinary conditions. The mill treats about 45 tons in

24 hours, and produces as an average 7½ tons of concentrates. Three men are required for each shift: one for the crusher, one for the stamps and tables, and one for the transport of concentrates.

The total cost of running this mill, day and night, is made up of the following items:

4 men for crusher and transport of concentrates, at $1.75	$7.00
2 mill men, for stamps and tables, at $2.25	4.50
Supplies	1.50
Electric power, 65 h.p., at $35 per year	7.58
Depreciation and repairs (10% on total cost of $25,000)	8.33
	$28.91

The average cost of concentration per ton of ore amounts, therefore, to $28.91 ÷ 7·5 = $3.85.

It is evident that this amount can be reduced somewhat by increasing the capacity of the mill by the addition of 20 stamps, as no more labour will be required for such a mill than for one with 20 stamps.

It must be said, however, that the capacity of a mill, the quality of the concentrates, and the condition of the tailings, depend largely—apart from the design of the mill—upon the intelligence and reliability of the men employed, and a saving made in the wages may be more than offset by losses in the efficiency of the machines, due to ignorance or neglect.

CHAPTER V

MARKET PRICES AND STATUS OF THE CANADIAN INDUSTRY.

The principal market for Canadian chromite is the United States; only a very limited quantity being consumed in Canada. No duty is paid on chrome iron ore sent to the United States; but there is a tariff on all compounds, [illegible] articles manufactured therefrom. Most of the crude ore mined is sold for furnace linings, to steel works; the occasionally high amount of silica contained in the mineral sometimes as much as 10 per cent being no more a barrier to its application. A maximum of 4 per cent of silica some 5 years ago was all that was accepted, but to-day ore containing as high as 8 per cent of silica is readily bought for that purpose.

[illegible] the concentrates is used in the chemical industry: [illegible] manufacture of bichromates. The prices for chrome iron ore [illegible] for the last 15 years. In 1895 as high as $20 and $21 per gross [illegible] f.o.b. station, was paid. In 1899 the price dropped to $17 and $18, and to-day it is $14 and $15, with an ascending scale of 50 cents per unit.

[illegible] merchantable grade for the manufacture of bichromate of potash is 50 per cent chromic oxide, but some buyers accept only 49, and even 48 per cent. The high grade ore, hand sorted and cobbed, containing 50 per cent Cr_2O_3, brings $15 per ton.

On ores containing over 50 per [illegible] premium of 50 cents per unit is paid, whereas on ores below 50 [illegible] deduction is made of 50 cents per unit, down to 48 per cent.

The second-class ores contain [illegible] per cent Cr_2O_3: $12.25 is paid for 45 per cent ore, and a premium [illegible] unit up to 48 per cent is allowed.

All crude ores below 45 per cent and [illegible] per cent are designated as third-class ores. They bring only $9.50 per ton; and 50 cents per unit is added or deducted for every unit above or below 40 per cent.

The concentrates are generally divided into two grades. The first grade, containing 50 per cent and above, brings $13 per ton, and 50 cents per unit is added or deducted down to 45 per cent. The second grade ore, or the middlings from the Wilfley tables running below 45 per cent, bring about $9 per ton.

PERCENTAGE OF GRADES PRODUCED IN THE MINES

The statistics for 1904, 1905, 1906 and 1907, show that the mines have produced on an average the following percentages in quality:

No. I crude, from 6 to 10 per cent.

No. II crude, from 35 to 40 per cent.

Concentrates, from 50 to 60 per cent.

In the mills usually a concentration is effected of 4, 5, and 6 to 1: in other words 4, 5, or 6 tons of milling rock yield one ton of concentrates.

STATUS OF THE CHROMITE INDUSTRY.

The mining for chrome iron ore in the Dominion of Canada, which some six years ago was still in its infancy, has assumed such a character of stability, as will, in the near future, entitle it to a prominent position amongst the mineral industries. Formerly, mining was carried on in a spasmodic manner, that is to say, deposits were only tested superficially, and as soon as a little dead rock threatened to cut off the deposits, operations were suspended. Many of the smaller producers worked intermittently, taking out only the ore which appeared on the surface, and stopping work when the deposits were —in their opinion —exhausted.

These erratic methods, and constant shifting of operations from one place to another, proved too expensive, and with the difficulty of disposing of, or working the lower grade ores, it was apparent that the industry lacked permanence, and the possibility of giving fair returns.

With the advent of a proper milling practice some six years ago, a new era has set in, and many a mine, which was working on poor ground and could not produce the higher qualities, has now a chance to realize on the abundant quantities of low grade ore, which are in evidence at almost all the pits worked in former years; and further, while formerly the chromite industry was in the hands of small individual operators, having in most cases a very limited amount of capital at their disposal, to-day powerful companies owning extensive areas of chromite lands through the district, have commenced operations on a large scale.

Another difficulty which seriously handicapped the progress of this industry was the question of finding a market. There was at one time a prejudice on the part of users of chromite in the United States, against Canadian chrome iron ores as not being so well adapted to certain applications as those coming from Asia Minor; but all this has now disappeared, and the Canadian chrome iron ore holds its own in the many applications for which the mineral is adapted. At the present time there are in operation 75 stamps, with a total approximate capacity of 150 tons of milling rock per day. Three companies only are at present producing, that is, the Black Lake Chrome and Asbestos Co., at Black lake; the Canadian Chrome Company, near Thetford, and the American Chrome Company, operating around Black lake. In the summer season about 150 men are employed.

As to the future possibilities of the productive chromite fields of Canada, located in the Eastern townships, there is no doubt that the future outlook for a production of a large tonnage is very bright, and if Canada should ever be called upon to furnish four or five times the quantity of ore produced to-day, the writer is of opinion that the deposits at present under development, as well as those lying idle but which were worked some years ago, can deliver this quantity for years to come.

CHAPTER VI.

THE CHROMITE MINES OF CANADA.

HISTORY.

The first discovery of chromite in Canada was made in 1846 and 1847, in the township of Bolton, on lot 26, range vii. A sample from a vein 1 foot thick, gave Dr. Hunt, of the Geological Survey, an assay of 45·90 per cent oxide of chromium. Near the lower end of Memphremagog lake, from a vein apparently 18″ wide, a large block of the mineral was taken, weighing 600 pounds, which when analysed gave 49·75 oxide of chromium. Reference to these two occurrences is made in the reports of the Geological Survey for 1847-8. In 1864 about ten tons were extracted from a deposit in the vicinity of Lake Nicolet, in the township of Wolfe, and in 1886-7 a small quantity was taken out on lot 24, range iii of the township of Wolfstown. In 1887 Dr. Reed shipped to Philadelphia 54 tons obtained from lot 1, range x of Leeds; and from lot 16, range iv of Thetford, four or five tons were shipped. About the same time specimens of the ore were sent to the Antwerp exhibition, which caused a great many inquiries to be made regarding the deposits

In April, 1894, an unknown mineral was found in the vicinity of Black lake, by a man named Provencal. The mineral was recognized by Mr. Obalski, the government mining engineer, as chromite. Subsequently the Nadeau-Provencal mine was opened, and as the prices paid for the mineral were rather tempting, prospectors soon located quite a number of deposits, mostly in the township of Coleraine. However, mining dragged along in a spasmodic manner until 1898-9, when the first efforts were made to work the deposits on a more substantial scale, and to utilize the low grade ores, which had been accumulating on the dumps, from the concentration mills.

THE BLACK LAKE CHROME & ASBESTOS COMPANY.

This Company is the largest producer and at the present time owns most of the productive chrome iron ore properties in the Eastern townships of Quebec. Their holdings comprise a parcel of land designated as Block A and B of the township of Coleraine, and bordering the upper or southern end of Black lake. The area of this block covers 6,006 acres. This Company took over all the chromite mines and a lot of virgin ground from the Coleraine Mining Co. Before entering into a description of the present works, a brief outline will be given regarding the history of the Company.

The Coleraine Mining Company came into possession of a number of mines in 1897, and began working on the spot where shaft No. 1 is now located. In that year about 2,000 tons were mined from this pit alone; while from all the mines something like 7,000 tons were extracted, of which 5,500 tons were shipped to the United States. The Company, realizing the great importance of utilizing the low grade ores which were accumulating at all their pits, installed, in 1898, a concentrator on the shore of Black lake, 150 feet below the track of the Quebec Central railway. Work was continued until 1901, with a force of from 60 to 80 men. In 1899, the low grade ores were, for the first time, treated in the mill; but the actual results obtained were disappointing. Frequent changes in the management took place and a number of additions, changes and improvements in the mill were [illegible] without realization of what was expected from the works, hence in 1901, work was entirely suspended at mine and mill. In 1902 the present Company took over all the mines, the mill, and the large block of unexplored land, and since that time, owing to the energetic and practical way things have been conducted, the undertaking has been placed on a substantial business basis. Most of the credit for the development of our chrome iron ore resources is due to this Company, which has spared neither means nor effort to bring this industry, which at one time threatened to fall to pieces, to a successful issue.

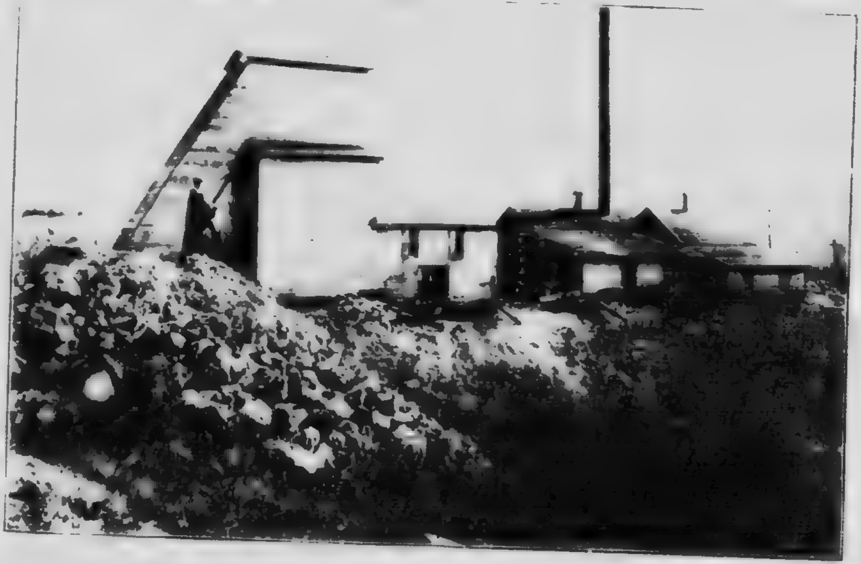
The Black Lake Chrome & Asbestos Company is at present working in three locations: (1) pit No. 1, close to the road leading from Black Lake to Coleraine; (2) pit No. II, or the old Caribou pit, close to Caribou lake; and (3) the No. III, or Montreal pit, about 8 miles east of the railway, on lots 25 and 26, range ii, Coleraine.

Pit No. 1 is by far the largest producer of chrome iron ore in the Eastern townships. It is calculated that this mine has produced more chrome iron ore than all the other mines together. The main shaft is on the slope of a gently rising hill, about 1,500 feet to the south of the mill, on the track of the Quebec Central railway. An inclined tramway, operated by a small double cylinder hoisting engine, connects pit and mill; the difference in level between pit mouth and ore bin being 85 feet. The pit itself represents on the surface an irregular opening, shaped after the ore deposit, about 120 feet long and 50 feet wide. At a depth of about 80 feet the ore body takes a sudden pitch, and in following the same towards depth it was found that the deposits, both in length as in width, increased considerably, the width in some places between enclosing walls being 45 or 50 feet. Two skipways with self dumping skips, operated by a hoisting engine on the surface, and following the general dip of about 60°, serve as a means of getting out the ore. In this way the deposit was developed and worked to a depth of 340 feet; however, the dangerous condition of the overhanging roof in the shaft rendered working in the latter very dangerous, and it was decided to stop operations therein altogether, pending the sinking of a new shaft. This new shaft was started at a point close to the old pit, about 50 feet distant.

PLATE VII

Thirty Stamp Mill of the Black Lake Chrome and Asbestos Co., Que.

PLATE VIII



Surface Shaft and Equipment of Pit No. 1 of the Black Lake Chrome and Asbestos Co., Que.

Its inclination is 60 degrees, and its dimensions 6 × 10 feet inside timbers. At present it has attained a depth of 300 feet, and sinking is to be continued to below the 340 foot level. At the 250 foot level a cross-cut will be driven to a body of ore, which had been left as a safety pillar in the early workings; while at the 340 foot level the lower part of the same ore body will be reached by a second cross-cut.

The Company has spared neither money nor means to find out by diamond drilling the extent of the deposit, both as to depth and lateral extension.

Two samples designated as No. 1 and No. 2, and taken from the ore dumps at shaft No. 1, gave, according to Mr. H. A. Leverin, chemist to the Mines Branch, the following percentage composition:—

	1	2
Oxide of Chromium (Cr_2O_3)	43·57	51·18
Silica (SiO_2)	12·62	7·48
Alumina (Al_2O_3)	13·90	11·35
Lime (CaO)	0·20	0·40
Magnesia (MgO)	3·83	2.62
Iron Protoxide (FeO)	17·61	19·80
Metallic Iron (Fe)	13·70	15·40

The power plant at pit No. 1 consists of a 5 drill Rand air compressor, actuated by an electric motor, furnishing air for hoisting, drilling, and pumping. As soon as shaft sinking is completed, it is the intention to furnish the pit head with an up-to-date and adequate machinery plant.

The mill, which is located—as already mentioned—about 1,200 feet from pit No. 1, is composed of a 30 stamp battery; a 12″ × 15″ Blake crusher, and 7 Wilfley tables. The ore is dumped into a 100 ton bin, and after passing through the crusher, is fed by automatic feeders to the stamps. The latter weigh 1,100 lbs. each, with an average drop of 10 inches. The pulp of each battery of 5 stamps is discharged through a pipe to a Wilfley table. Each table produces heads, middlings, and tailings. The heads are pure enough to be shipped after drainage; the middlings from all six tables are carried in a launder to a separate Wilfley table, which makes two products—heads and tails. These heads are not pure enough for shipment, and are treated again in the mill. Water is supplied to the mill by an electrically driven pump, placed on the lake shore. A 100 h.p three-phase induction motor supplies all the power for the mill.

The Caribou pit, located on the northern border of Caribou lake in the slope of a hilly range, is reported to have delivered large quantities of crude; and the Company realizing the excellent character of the deposit is having this mine put into proper order. From the surface outcrops it appears that the trend of the ore-bearing formation is about 75 degrees west of north. A granitic dike, having a width of from 25 to 30 feet, divides the serpentine into a southern and northern part. In the southern part a pit has been sunk all along the granitic dike, to a depth of 100 feet, measuring on the surface approximately 60 × 90 feet. Rich ore chutes have been found all along this dike, and at the time of the visit by the writer, apparently a large pocket was tapped at a depth of about 60 feet, yielding a large percentage of crude of excellent quality. Besides this occurrence there can be seen all along the brow of the hill a number of excellent outcrops of ore, upon which no work of any extent had been done.

The plant consists of a substantial derrick, hoisting engine, and boiler. A small 10 stamp mill had been erected on the premises close to the big pit, but was subsequently dismantled. This mine was situated at a distance of 2½ miles from pit No. 1, a good wagon road connecting them.

The Montreal mine of this Company is located on lot 26, range ii, Coleraine, at a distance of seven and a half miles from Chrome siding, to the east of the railway. All the ore is shipped to this station, good roads connecting it with the mine.

This property, which comprises lots 25, 26, in range ii, and lot 26 in range iii, was purchased from the Government in 1894, by Messrs. H. and T. Leonard, D. Morin and A. Labrecque.

The surface showings on these properties, it is reported, were some of the largest ever found in the district, but the ore was not high grade, yielding not more than 45 per cent of chromic oxide. The mines were, according to Mr. Obalski's report, worked up to 1900 in a most primitive manner, no machinery of any kind being used. Up to January 1, 1900, some 3,200 tons had been extracted, of which 2,200 tons were sold; and a far larger quantity could have been shipped if the demand for this low grade ore had not been so limited. In 1901 the Montreal Chrome Iron Company was formed and in 1902 a mill was built for the treatment of the low grade ores. This mill has a jaw crusher, and 15 stamps of 1,000 lbs. each; 3 concentration tables all driven by an 80 h.p. high speed engine, and a boiler plant consisting of 2 boilers of 50 h.p. each. Concentrates to the amount of 4½ tons per 10 hours were produced, and the ore was shipped over a good road 7½ miles long to Chrome siding. In 1903, during 5 months' operations from April to August, about 500 tons of concentrates were shipped.

[illegible] the Black Lake Chrome and Asbestos Company acquired [illegible] the properties belonging to the Montreal Co. The great amount of exploratory work done by the new Company for the purpose of determining the approximate tonnage of ore available in the deposits has placed this under- [illegible]

[illegible] mine property is located on the gentle slope of a mountainous range [illegible] It consists of a number of pits, cuts, and [illegible] length of 125 feet, the main trend of all these [illegible] most southerly [illegible] 75 [illegible] 125 feet [illegible] being about 30 feet. [illegible] advantage in this [illegible] pockets of crude

PLATE IX

Stamp Mill at the Montreal Mine, of the Black Lake Chrome and Asbestos Co

ore, granitic dikes cutting the serpentine, as well as the disturbances therein caused by the shifting of the whole formation. Slickensides and faults as a result of these movements are very frequent, and in some places have cut off entire ore bodies. In this case the cutting plane has a more or less polished surface, and is covered to some extent by soft slippery serpentine. The writer has taken from this pit ore with such highly polished surfaces that any one not acquainted with the outward features of the rock in the pit would suggest artificial cutting and subsequent polishing of the rock faces. The greater part of the data set forth in the description on pages 22 25 dealing with the general occurrence of the chrome iron ore deposits was obtained in this pit.

All the other pits located in a northwesterly direction from the main pit, consist of open-cuts, exhibiting the same features as those observed in the big pit. The Company has done considerable diamond drilling just north of the big pit. Through these operations it has been shown that the available ore body consists of quite a number of disconnected large pockets, with disseminated ore between. The exact dimensions of this ore-bearing formation cannot be given yet, but judging from the mining work and diamond drilling so far done, it appears that it has a length of at least 350 feet, with an average width of 60 feet, while the depth must be at least 75 feet. The ore located by diamond borings is at present taken out by a drift run in from the main pit, and the results so far obtained compare very favourably with those of the drill holes.

The mill at this mine is located about 400 feet from the main pit, and the system adopted is the same as that in operation at the mill of No. 1 shaft. The ore, after passing a jaw crusher, is fed to 15 stamps. The pulp then passes over 3 Wilfley tables, the middlings again being treated on a fourth table. The mill engine is a single cylinder Corliss engine, the steam being supplied by two 45 h.p. flue boilers.

Among the many pits which were worked in the nineties by the former owners may be mentioned the Frechette pit, at a distance of about one mile to the southeast of Black Lake, on the high mountain ridge overlooking the village. This pit is reported to have yielded over 1,000 tons of high grade ore. The principal opening measures 40 × 60 feet; but a closer examination could not be made on account of it being filled with water. The walls, however, show still some good ore, in a rusty and sometimes dark green serpentine. The concentrates obtained from some of this ore indicated over 60 per cent of oxide of chromium.

The camp at the Montreal mine consists of office building, sleeping house and kitchen, and several accessory buildings.

There will be employed, as soon as shaft No. 1 is completed, about 150 men in all the mines of this Company.

A sample of crude ore from the main pit was analysed by Mr. H. A. Leverin, as follows:

Oxide of Chromium (Cr_2O_3)	43·24
Silica (SiO_2)	8·26
Alumina (Al_2O_3)	7·12
Lime (CaO)	14·17
Magnesia (MgO)	4·00
Iron Protoxide (FeO)	17·74
Metallic Iron (Fe)	13·80

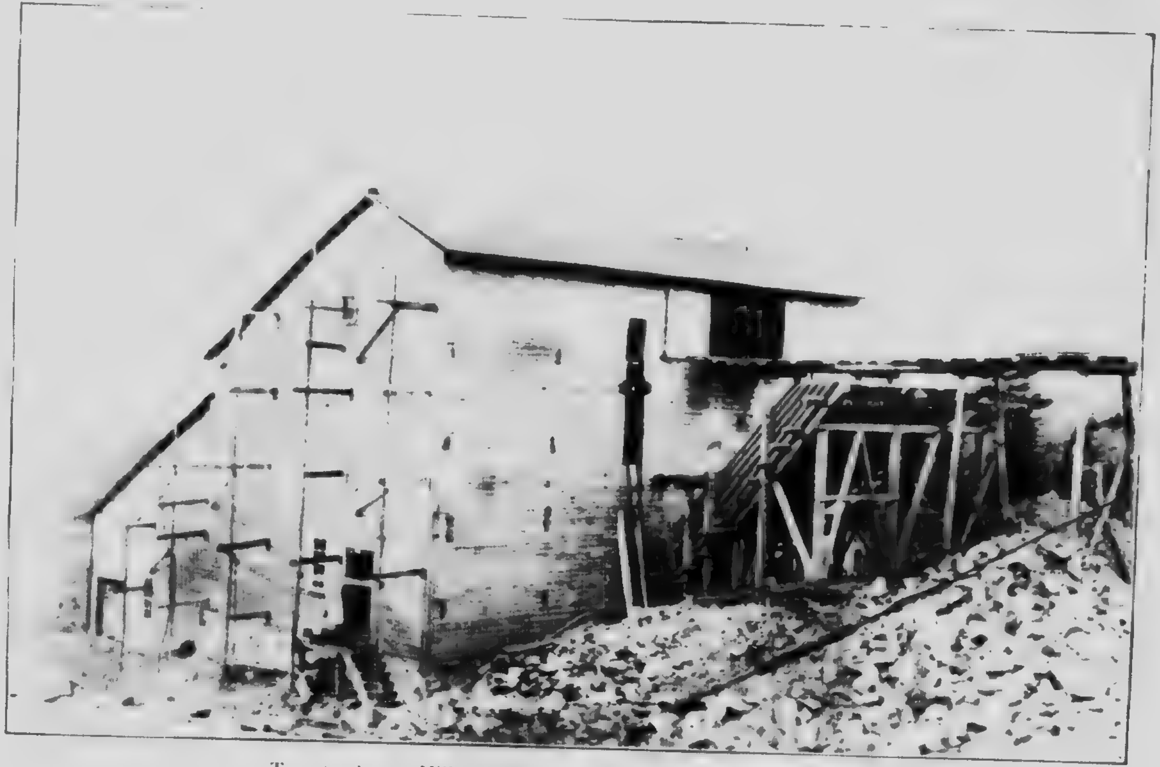
THE CANADIAN CHROME COMPANY

The mine of this Company is located on the southwesterly part of lot 16, range A, Coleraine, and was discovered and purchased from the Government in 1899 by Jos. Nadeau and R. Topping. About 1,700 tons of ore were produced before 1903, when the mine was taken over by the present Company. The distance from Black Lake or Thetford is about 5 miles; but the two miles of the road leading to the property are not in good condition. The principal pit measures on the surface 100 × 125 feet; its depth is 60 feet. The ore occurs here mostly in the disseminated or low grade form, very little crude being produced. Several granitic intrusions, running mostly in a northwesterly direction, can be noticed. One of these is 4 feet wide, and close to it occur a number of rich streaks of ore, delivering a high percentage of crude. The serpentine is generally of a soft quality, of dark green colour, with numerous cracks and slickensides. The latter are followed in several places by streaks of disseminated ore, which gives rise to the supposition that these fissures may have had some influence upon the formation of the ore. The slickensides of the serpentines are often coated with a fine film of very dark green rock, highly polished, probably composed of olivine.

There are several other pits close to the one described, but most of them are filled with water, and no examination can be made. However, the writer was impressed with the great amount of dumps lying on the property close to the various pits, exhibiting on closer inspection, quite a content of excellent milling ore. Judging from the appearance of these dumps it seems quite evident that the area over which these pits are distributed is a valuable one. The very irregular distribution of the disseminated ore at this mine seems to point to the open-cast method as the only one whereby the ore can be cheaply mined, and the writer has no doubt that if these pits were systematically worked under capable management in one large open-cut (suspending operations for three or four months in the severe winter season), the results would be quite different from those obtained under present working conditions.

The ore is delivered by tramway to the mill and dumped into a chute, which feeds into a jaw crusher; from which it is elevated and placed in the bin. Twenty stamps with 4 Wilfley tables are in operation, an extra Wilfley taking charge of the middlings from all the other tables. The entire mill is run by

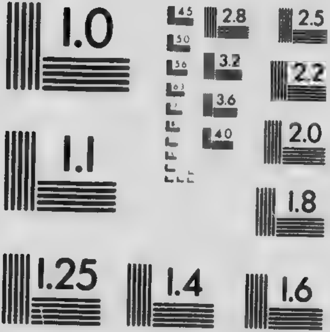
PLATE X



Twenty Stamp Mill of the Canadian Chrome Co., Black Lake

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No 2)



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electric power, supplied by the St. Francis Power Company, and delivered through a 100 h.p. three-phase induction motor. Water is furnished through a 3″ pipe from a creek a quarter of a mile from the mill; for the dry summer season enough water is stored by two dams, to supply the mill for several months. The concentration in the mill is about 6 tons of ore to one ton of concentrates.

The mine is equipped with a sleeping camp, kitchen, office, and accessory buildings for the accommodation of 25 men. At present 2[illegible] men are employed in mine and mill.

A sample of crude ore taken from the main pit, was analysed by Mr. H. A. Leverin, as follows:

Oxide of Chromium (Cr_2O_3)	45·95
Silica (SiO_2)	7·68
Alumina (Al_2O_3)	8·94
Lime (CaO)	0·12
Magnesia (MgO)	4·90
Iron Protoxide (FeO)	22·50
Metallic Iron (Fe)	17·50

THE AMERICAN CHROME COMPANY.

The principal shareholders of this Company are Messrs. Beebe Bros., of Boston, Mass., the well known manufacturers of chrome colours, and products used in the tanning of leather. The lots owned by the Company comprise the following numbers: in range iv, lots 7, 8, 9, and 10; in range xiii, lot 9; in range B, lots 6, 7, and 13, all located in Coleraine.

The principal work is carried on, on lots 6 and 7, range B. Most of the pits at the time of examination were filled with water, and little could be seen on the surface exposures. It appears that the ore occurs mostly in disseminated form, assuming when exposed to atmospheric agencies a decidedly brownish colour. There are altogether about six pits, the largest of them, No. 1, measuring on the surface 30 × 80 feet; the depth is reported to be 65 feet. The milling rock from this pit gave as an average 25 per cent of concentrates. Pits 2 and 3 are separated by a granitic dike 8″ wide, and on both sides of this dike, rich streaks of disseminated ore can be seen. Pit No. 2 measures about 50 × 60 feet on the surface, while its depth is reported to be 30 feet. No. 4 is a long cut, 125 feet long × 40 feet wide, following the trend of a disseminated ore body of considerable dimensions. The serpentine exhibits here all shades from light green to very dark. Granitic dikes of small dimensions are frequent, but accumulations of ore near these dikes could not be observed. The serpentine is as a general rule interwoven with fine, minute fissures and cracks, and the fissure planes are covered frequently with a coating of dark green serpentine, showing disseminated ore. It breaks up easily and very large pieces are seldom obtained. Frequently it takes a brownish tarnish, due to oxidation of the iron.

At the time of the visit of the writer, operations were carried on in a small pit some distance from No. 4, where there appeared to be quite a body of disseminated ore, some of it accompanying cracks and fissures in the rock. The mill is about one mile distant from the mine, on lot 9, range xiii. This was the first mill in the district in which stamps and Wilfley tables were used. The mill was built under the direction of Mr. Whitney, then manager of the Company 1901. It contained a Blake crusher, 2 pair of rolls, a battery of 5 stamps, and a Wilfley table with the usual accessories. The output was about 20 tons of concentrates per week, and in the first year of operation about 100 tons were obtained. Later on a number of improvements were introduced, and at present the mill contains 10 stamps, and 3 Wilfley tables. In 1905, about 500 tons of concentrates were obtained, which were all shipped to the Company's works at Boston. Water for the mill is pumped from a creek in the vicinity.

On all the other lots belonging to the Company, considerable work has been done, but of late operations have been confined to lots 6 and 7, range B.

LOT 26, RANGE B.

This property, known as the Ross lot, was worked to some extent in 1898 by R. P. Hall. Since then Mr. J. M. Johnston has taken out some 450 or 500 tons of ore under contract – 1900 and 1901; but from this date the mine has been lying idle. The main pit consists of an open-cut, 125 feet long, and from 12 to 15 feet wide, with a face 15 feet high: the direction of the pit being N.W. 35 degrees. Little crude ore can be noticed, but the disseminated variety is abundant, judging from the appearance of the walls and of the dump. Water for milling purposes can be obtained from Lake Caribou, which is about one mile distant.

A sample of disseminated chromite, analysed by Mr. H. A. Leverin, analyst to the Mines Branch, gave the following percentage composition:

Oxide of Chromium (Cr_2O_3)	12·76
Silica (SiO_2)	17·48
Alumina (Al_2O_3)	6·93
Lime (CaO)	0·93
Magnesia (MgO)	20·92
Iron Protoxide (FeO)	12·47
Metallic Iron (Fe)	9·70

LOT X, 19. N.W.

This property, containing about 250 acres, was divided into 11 lots after the discovery of chrome iron ore thereon. The owner is Dr. Reed, of Reedsdale, Que. A small part was worked by contract, the operators paying for first quality ore $5, and for second quality $3 per ton. The principal pit was the most westerly of all the workings, and located on lot 5. Some 524 tons of crude were taken out of a cut 200 feet long, and from 20 to 30 feet deep, the main trend of this pit being N.E. 42 degrees. The walls still exhibit at some places good milling material, and some crude ore can be noticed at the face of the cut.

All operations on this property were suspended in 1896, and no work has been done since. Judging from the condition of the various openings, and the dumps, there seems to be ample ground for the belief that a stamp mill could be kept running on disseminated ore obtained from the many pits all over the property.

A sample of crude ore taken from the principal cut was analysed by Mr. H. A. Leverin, analyst to the Mines Branch, and gave the following percentage composition:

Oxide of Chromium (Cr_2O_3)	43·41
Silica (SiO_2)	11·28
Alumina (Al_2O_3)	6·45
Lime (CaO)	0·12
Magnesia (MgO)	6·50
Iron Protoxide (FeO)	19·42
Metallic Iron (Fe)	15·10

PROPERTY OF THE STANDARD ASBESTOS COMPANY.

This Company operated, from 1895 to 1898, a number of chrome iron ore pits, located at the crest of the hill, at an elevation of 800 feet above the railway track, 1½ miles from Black Lake station. It was then known as the Anglo-Canadian Asbestos Company. All the pits which were under operation at that time were close together, and gave evidence of the irregular character of the occurrence of chrome iron ore. No exact data of these operations are obtainable; but it is reported that the pits yielded a large tonnage from 2,000 to 3,000 tons of high grade ore. The dumps contain good milling material, and it is believed that a mill could be run alone on part of them for some time. Large blocks of a dark green serpentine can be noticed in these dumps, containing the mineral in disseminated grains, and yielding evidently a good percentage of mill rock. The largest pit measures on the surface about 60 × 100 feet; it was filled with water at the time of the writer's visit. Another pit measures 15 × 20 feet, which was also filled with water, and there is also a cut into the hillside 60 feet long and from 6 to 8 feet wide. The walls of this cut still exhibit good disseminated ore in a rusty looking serpentine.

Close to the southwesterly boundary of the property, and to Caribou lake, some 15 pits, cross-cuts and excavations can be seen. These were worked about 10 years ago for crude ore, some of the remaining dumps exhibiting good milling material.

LOTS 4 TO 7, RANGE XIII, COLERAINE.

Several prospects of good chrome iron ore have been located on these properties, especially on lots 4 and 5; but no extensive operations have yet been carried on.

LOT 8, RANGE XIII.

This property was first worked in 1894-5, by R. Topping, who mined about 50 tons of good ore. The main pit, in which some work has been done lately, consists of a cut 75 feet long, and from 8 to 10 feet wide. Disseminated and crude ore in light green coloured serpentine, as well as small granitic intrusions with disseminated ore alongside, can be noticed in a number of places. In one pit a fissure in serpentine is accompanied on one side by a solid vein of chrome iron ore from 4" to 6" in width, with gradations of disseminated ore over a width of 2 feet down to pure serpentine. The cut as a whole exhibits quantities of good milling material.

LOT 25, RANGE III.

Some chrome iron ore has been found on this property, but no mining has been done.

LOT 5, RANGE IV.

An outcrop of disseminated ore has been discovered in clearing the land for the erection of electric power poles. A band of ore 8 feet long, and several inches wide, occurs on a rock exposure. No mining has been done. The distance from D'Israeli is 4 miles, but access is difficult at present.

A sample of disseminated ore from this outcrop was analysed by Mr. H. A. Leverin, as follows:

Oxide of Chromium (Cr_2O_3)	18·57
Silica (SiO_2)	25·22
Alumina (Al_2O_3)	4·79
Lime (CaO)	0·10
Magnesia (MgO)	24·72
Iron Protoxide (FeO)	15·30
Metallic Iron (Fe)	11·90

LOT 25, RANGE IV.

In 1895 some work was done on several prospects, and a carload of good ore shipped.

LOT 17, RANGE A.

Here several propects were located. Little work has been done, however, though some ore has been mined and shipped.

Lot 23, Range B.

This property has been worked intermittently by Mr. Blondeau, but no large shipments were made.

IRELAND TOWNSHIP.

Lot 28, Range X

An open-cut near the crest of a hill exhibits a band of disseminated ore, 8″ wide, 25 feet long, and apparently terminating in what appears to be a considerable deposit of disseminated chrome iron ore.

It is reported that some 50 tons were obtained from this pit, and there is every reason to believe, judging from the indications, that a large tonnage of good milling ore could be mined here. The distance from Coleraine station is about 2½ miles, but the roads are not in a good condition for transportation. This property, as well as several others in the immediate vicinity, belongs to the King Brothers Company, of Thetford. A sample of crude analysed gave 45·85%.

Two samples of disseminated ore taken from the principal pit were submitted to analysis by Mr. H. A. Leverin, as follows:—

Oxide of Chromium (Cr_2O_3)	23·27	27·55
Silica (SiO_2)	21·30	20·76
Alumina (Al_2O_3)	6·52	8·10
Lime (CaO)	0·10	0·10
Magnesia (MgO)	17·75	12·96
Iron Protoxide (FeO)	15·20	15·82
Metallic Iron (Fe)	11·80	12·30

WOLFESTOWN TOWNSHIP.

Lot 24 in Range II, Lots 23, 24 and 25 in Range III and Lot 26 in Range IV.

Quite a number of prospects of chrome iron ore have been found all over these properties; but no development work, or mining to speak of, has been done: the companies owning these properties being more interested in asbestos than in chromite.

GARTHBY TOWNSHIP.

Lot C, Range I, near Breeches Lake.

Some carloads of chrome iron ore, running 55% oxide of chromium, were taken from this property by H. Leonard, in 1894. The distance from D'Israeli on the Quebec Central railway is 9 miles. Lots 5, 6, 7 and 8, of range ii, were acquired from the Government by the same party, and some work has been done on lots 6 and 7.

A deposit of chrome iron ore was also discovered on a small island in Breeches lake many years ago, but no mining of any extent has ever been attempted.

LOTS 36 AND 37, RANGE V.

Chromite occurs on the crest of a hill in a deposit of apparently considerable dimensions. The principal pit measures 30 × 20 feet, but at the time of the writer's visit it was filled with water. It is reported that some good crude ore has been shipped from here, but the exact quantity could not be ascertained. The dumps on the several pits show some good milling material. The property belongs to Mr. O. Brousseau, and is 2 miles distant from D'Israeli.

SOUTH HAM TOWNSHIP.

LOTS 24 AND 27, RANGE I.

Outcrops of chrome iron ore have been found on these lots, but no attempt has been made to develop or exploit them.

LOT 4, RANGE II.

According to Mr. Obalski, some ten tons of chrome iron ore, yielding 43·9% oxide of chromium were shipped from this property in 1861, by a Mr. R. Leckie. Deposits of chrome iron ore have also been found on lots 20, 21, and 27, in range II, but so far not much work has been done on them.

LOT 21½ W., RANGE I. NORTH OF LAKE NICOLET.

Here a remarkable deposit [illegible] iron, associated with chromite, occurs on the contact of the [illegible] the Cambrian schists. A little pit 12 feet deep has been sunk, [illegible] about 100 tons were extracted. An analysis of this ore gave [illegible] cent oxide of chromium, and the economic value of the deposit seems doubtful.

All these mines are situated at a distance of from 10 to 12 miles from Garthby station, on the Quebec Central railway.

THETFORD TOWNSHIP.

LOT 16, RANGE IV.

Some crude ore occurs here at several places, but as no mining has been done, nothing further can be said regarding these prospects. This property belongs to Dr. Reed, of Reedsdale.

LEEDS TOWNSHIP.

Lot 1, Range X.

It is reported that Dr. Reed, the owner of this property, took out 54 tons of chrome iron ore, which analysed 51 and 52 per cent, and which was shipped to Philadelphia, via Robertson station, in 1887. No work of importance has since been done on this property. The distance from Robertson station, on the Quebec Central railway, is 12 miles.

BOLTON TOWNSHIP.

Lot 9, Range VII.

In 1896-7, according to Mr. Obalski, 27 tons of chromite, analysing 49 per cent, were shipped from this property to Liverpool. No extensive operations were carried on, but the results obtained from this deposit justify further work. The property is situated at a distance of 4 miles from Eastman, on the Montreal-Sherbrooke line of the Canadian Pacific railway. Prospects of chromite have also been discovered on lots 13, 23, and 26½ of the same range, and on lot 13, range iv, and lot 26, range vi.

BROMPTON TOWNSHIP.

Lots 25 and 26, Range IX.

Work has been done by Mr. T. McCraw in the vicinity of Lake Brompton on some prospects of chrome iron ore, but so far with little result.

GASPÉ.

Mr. Obalski explored a mass of serpentine of considerable extent on Mount Albert, in 1897, at the head of the Ste. Anne des Monts river, in Gaspé, and he reports thus regarding the occurrence of chromite:

"In Gaspesia there is a great mass of serpentine, forming Mount Albert, which has an altitude of 3,700 feet, at the head of the Ste. Anne des Monts river. This mountain was pointed out long ago by the Geological Survey as containing chromic iron. I made an exploration in the summer of 1897, and particularly examined the plateau forming the summit, which presents a surface of not less than 25 square miles completely bare of vegetation, the rock being fully exposed everywhere. In fact I found some pieces of chromic iron, and even some small veins from 2″ to 3″ thick, but I saw nothing to justify work being done. There is a strip of black and heavy hornblende which may have been taken for iron by inexperienced explorers. This region is, moreover, difficult of access, being situated 35 miles from the Gulf of St. Lawrence, the only way to it being by the Ste. Anne river, which is itself not easy to ascend, to say nothing of the height of the mountain."

SUMMARY.

CHROME IRON ORE LOCALITIES IN THE PROVINCE OF QUEBEC.

COLERAINE:

Blocks A and B, comprising about 6,000 acres, belonging to the Black Lake Chrome and Asbestos Co.

Part of Block A, belonging to the Standard and Dominion Asbestos Co., near Black Lake station.

Range A, lots 15, 16, and 17.

Range B, lots 6, 7, 13, 23, 26, and 28.

Range ii, lots 25, 26, and 27.

Range iii, lot 25.

Range iv, lots, 5, 7, 8, 9, 10, and 25.

Range x, No. 19, N.W.; lots 1, 2, 3, 4, 5, and 6.

Range xiii (Indian Reserve), lots 2, 5, and 8.

Wolfestown.—Range ii, lot 28; range iii, lots 23, 24, and 25; range iv, lot 26.

Garthby.—(Near Breeches lake).—Range i, lot C; range ii, lots 5, 6, 7, and 8.

Breeches Lake island.—Range v, lots 36, and 37.

South Ham.—Range i, lots 24, and 27; range i, lot 21½ W., north of Nicolet lake; range ii, lot 4.

Thetford.—Range iv, lot 16.

Leeds.—Range x, lot 1.

Bolton.—Range iv, lot 13; range vi, lot 26; range vii, lots 9, 13, 23, and 26½.

Brompton.—Range ix, lots 25 and 26.

Gaspé.—On Mount Albert.

CHAPTER VII.

CHROME IRON ORE IN FOREIGN COUNTRIES.

The chief source of supply of chromite, from which all the metallic chromium and chromium salts are obtained, are the deposits in New Caledonia, and in European and Asiatic Turkey. The deposits in these countries have for many years practically controlled the market for chrome iron or The United States obtains its principal supply from Canada, and from Asiatic Turkey; but since the rapid development of the New Caledonia deposits it has been obtaining a certain quantity from that locality. The increase in the production of the mineral in the latter country will have a tendency to reduce somewhat its price on the New York market. In addition to these two countries, chromite is mined in small quantities in Russia, India, Australia, Greece, and Newfoundland.

From what can be seen in the literature on the subject of chrome iron ore deposits in foreign countries, it seems that all the deposits occur as irregular masses or pockets similar to the Canadian deposits. There is one occurrence, however, which calls for special attention, and that is the one mentioned by Mr. Glenn, called the Wood pit, on the Octoraro river. According to Mr. Glenn, this deposit appears to be truly an ore chute, a vein similar to the copper occurrences in the crystalline rocks at Capelton, in the Province of Quebec, or at Ely, or Elizabeth, in the State of Vermont. The deposit in the Wood pit has a perfectly well defined and smooth foot-wall, pitching about 60 degrees for 300 feet, and about 45 degrees for 400 feet. The lower 400 feet is a warped surface, which bends through a quadrant to the left as one looks down the incline.

UNITED STATES.

Although the mineral chromite occurs widely distributed through the southeastern section of the United States, associated with [illegible] magnesia rocks, there are few localities where it is found in sufficient [illegible] of commercial value. Compared with the great demand th[illegible] very inconsiderable.

The mineral has been found in quantity in Pennsylvania, Maryland, North Carolina, and California; but for the last few years, on [illegible] of the low price at which foreign chromite ores can be imported into [illegible], there has been but little mining undertaken for these ores. It [illegible] however, that the existing chromite deposits are not by any means [illegible], and if the foreign deposits should slacken in their supply, which [illegible] to increase the prices, then there would be a great chance to exploit th[illegible] a much larger scale, with a fair margin of profit.

In California and North Carolina the mines have been working intermittently, and the competition of foreign ores has to a great extent worked against any expansion of the mining industry. The greatest obstacles are their remote situation from points of consumption, and the consequent high freight costs.

In former years chrome iron ore was mostly imported from Turkey. This ore is generally of good quality, though somewhat inferior to the best ore from North Carolina. That from the Macri mines carries from 48 to 5' per cent oxide of chromium, while the product of Doghards runs about 54 per cent.

New uses for chromite have stimulated the working of some of the deposits. The use of chromite for furnace linings, for the smelting of copper and other ores, has had already a beneficial effect on the exploitation of the deposits in California and North Carolina.

Along the Pacific coast basic magnesian rocks are found in abundance, especially in California, where they are known to outcrop in at least thirty counties. Associated with many of these rocks is chrome iron ore. In a number of localities in this region it has been mined, at one time before ores from Turkey came on the market

The deposits in the neighbourhood of San Luis Obispo practically furnished all the chrome iron ore used in the United States. A peculiar feature in the placer deposits of California is the presence of more or less platinum. Wherever platinum has been found in place, it is associated with peridotite rocks, and with chrome iron ore.

In California chromite ores are found in the following counties: Alameda, Calaveras, Del Norte, Fresno, Mendocino, Napa, Placer, San Luis Obispo, Santa Clara, Shasta, Sierra, Sonoma, and Tahema. Serpentine and other basic magnesian rocks occur very extensively in these counties. Although the production so far has been small, the deposits in some of these counties, especially in Shasta county, promise to be of considerable extent.

Chrome iron ore is being shipped from the Dougherty and Brown mine at Shotgun creek, Shasta county, to several smelting plants, for furnace lining. The production amounts at present to only a few hundred tons a year, and this must be used on the Pacific coast; since freight rates to the east from San Francisco are too high for the domestic product to compete with the imported ore, east of the Missouri river. At one time several thousand tons were mined annually in California and shipped by sailing vessels to the east. As sailing vessels ply no more from San Francisco to points on the Atlantic coast, no shipments are now made, and most of the chrome iron ore mines have been closed down as unprofitable. The local demand is small and only warrants mining the best grade of ore.

In North Carolina the chromite deposits of Yancey county give indications of containing large bodies of this mineral, and there is a great possibility that with the construction of the railway from Erwin, Tenn., to

Marion, N.C., these localities will produce some good ore at such a low figure as to compete successfully with the foreign ores. According to Hyde Pratt, prospecting for chrome iron ore in that State was first undertaken over 30 years ago, and has been continued spasmodically ever since, but there never has been any systematic development work done. The chrome iron ore is nearly uniform in general character throughout the entire area, being very hard and compact, though often of a fine granular appearance, and there is but little ore that is friable.

The masses of chromite are usually very free from seams of peridotite, or its alteration products. This simplifies the concentration, and a high grade ore can usually be obtained by cobbing and hand picking.

In Yancey county, one of the two most important deposits in the State occurs at Mine hill, on the Mine fork of Jack creek, 5 miles north of Burnsville, the county seat, on the Bakersville road, where a large peridotite (dunite) formation outcrops on both sides of the road. Seams or pockets of chromite ore are abundant in this peridotite, varying from ½" to 3" in thickness. Near the summit of the hill, on the east side of the road, about 150 feet above the road and stream bed, a deposit of chromite has been opened, from which 25 tons of ore were taken. A large part of this ore still remains on the dumps. A pit 9 feet deep was sunk on the deposit; but this has been filled with water since the work ceased, so that no estimate can be made of the extent of the deposit. Mr Garrett Ray, of Burnsville, N.C., the owner, reports that the chromite widened to between 2 and 3 feet at the bottom of the pit. There are other promising seams or veins, which appear to indicate the existence of a deposit of chromite ore near the contact of the peridotite and gneiss.

On the extreme western slope of the formation a trench has been cut 30 feet or more into the hill, in which are exposed many small pockets of chromite. The work done in this trench is of a prehistoric character, and whether the object of the exploration was chromite or not has never been explained.

With the exception of the pit sunk near the summit of Mine hill, from which a few tons of ore were shipped, no mining has been done here, and very little prospecting has been undertaken to determine the exact extent of the chromite deposits. The distance from the railway has greatly discouraged systematic prospecting in this region. The shipping point at the time this work was done was Asheville, on the Southern railway, about 40 miles to the south. The railway from Erwin, Tenn., to Marion, N.C., which is now partially completed, passes within 3 or 4 miles of this locality.

About 9 miles west of Burnsville, near Price creek, there is a narrow bed of peridotite, a quarter of a mile from Price Creek post-office. A pocket of chromite discovered here yielded nearly 7 tons of ore. This exhausted the pocket, and since then no prospecting has been done in this vicinity.

In Jackson county, in the vicinity of Webster, there is a large peridotite formation, extending from about half a mile north of the town to a mile and a quarter south.

The only deposit of any note found on the north or Webster side of the river is on the east side of the Tuckaseegee road, about 200 yards from the main street of the town. A pocket of chromite was uncovered here, which yielded a number of tons of chromite, most of which was shipped. At a depth of nearly 9 feet the pocket pinched out, leaving but a small seam of chromite in sight. Many small seams and pockets of chromite are to be seen, but no other work has been undertaken for chromite on this side of the river.

On the south side of the river, following closely the contact of the dunite with the gneiss, a line of prospect pits has been dug which shows the presence of a considerable amount of chromite. The most promising deposits are: one on the land of James Ashe, where a cut 25 feet long, 6 to 8 feet wide, and 8 to 10 feet deep, was sunk on a vein of chromite 12″ to 18″ thick, which at the bottom of the cut is 12″ thick; and another on the land of Daniel Fullbright, where a seam nearly 12″ thick is exposed in the branch. The nearest shipping point is Sylva, on the southern railway, 3 miles north of Webster.

Chromite has been found at a number of places in the masses of peridotite, within 2 or 3 miles southwest from Balsam gap, Jackson county. The most promising outlook for a large deposit is on Dark Ridge creek, about 525 feet south of the Dark Ridge trestle of the Murphy branch of the Southern railway. Analyses show the ore to carry about 49 per cent of Cr_2O_3. The property is owned by the Highland Forest Company, of Waynesville, N.C.

No large deposits of chromite have yet been found in North Carolina, but the work done shows that extensive deposits may exist in the State, those described above being the most promising ones known.

Pennsylvania and Maryland are the two States where formerly chrome iron ore was mined to a large extent. The first supply was obtained from Chester and Delaware counties, Pa., and Cecil and Harford counties, Md. The largest producer of ore was the Wood chrome mine, not far from the Horsefoot ford on the Octoraro river. The history of this and other discoveries in Harford and Baltimore counties has been described on page 4.

Professor Frazer[1] gives a graphic account of the famous Wood mine, fifty-two years after its discovery, in the following words:—

"The Wood pit was opened in 1828, and was worked to about 1880, except from 1868 to 1873. The total output was about 95,000 tons of chrome iron ore. Of late years only a small force has been employed, producing 500 tons to 600 tons of ore yearly. The assay value varies, as with other kinds of ore, but within smaller limits.

"The country rock is serpentine. The ore-body, as proven, is almost 50 fathoms long at its greatest extension. Depth proved to 120 fathoms. Pitch of the mine is from 40 degrees to 60 degrees under the horizon. The strike is nearly east and west at the outcrop, and nearly north and south on lower levels. The width of the ore-bearing rocks is from 10 to 35 feet, or n[illegible] be taken generally at 20 feet. In this space occur the chrome iron ore and gangue (mostly serpentine), which show a general attempt at stratification, conforming to strike and dip of the mine. But occasionally a branch of ore will stand vertically, and extend itself into the foot-wall; or it may be horizontal, and do the same thing. The mine is worked by ordinary 10 fathom levels, winzes, etc.

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[1] Second Geol. Survey, Penn., 1880, p. 192.

"This mine is famous throughout the civilized world for specimens of minerals which it has furnished to all cabinets . . . . . The ore is thrown out almost pure, and without admixture of gangue . . . . . About 5 per cent of the ore is crushed and washed, the remainder being pure enough to ship without washing . . . . . The serpentine which forms the country-rock here is unstratified, and is about ¾ of a mile (or 1·3 kilometer) in breadth. The strike of the vein is about west 12 degrees south . . . . . The sandy chloritic slates to the north of the mine dip south 50 degrees."

Most of the chromite ore that has been obtained from Maryland has been in the form of sand. South of Baltimore diligent search has been made for chromite, but no deposits of commercial value have been discovered.

The valuable chromite territory that is known to exist in Pennsylvania, or Maryland, lies in a strip of land extending from Soldiers Delight, 16 miles northwest of Baltimore, to the Boone farm, 10 miles east of the Wood mine, making a total distance of about 60 miles. There are still valuable chromite sand deposits in this section, but they cannot compete with that imported from Turkey.

NEWFOUNDLAND.

The chromite deposits of Newfoundland were described by George W. Maynard, at the Chicago meeting of the American Institute of Mining Engineers, February, 1897.[1]

The deposits are located at Bluff-Head, Port au Port bay, on the west coast of Newfoundland, in north latitude 48° 45′, thirty miles from Sandy point, on Bay St. George, which is reached by steamer from Halifax, and North Sydney, Cape Breton. Bay St. George is separated from Port au Port bay by a narrow neck of land, called The Gravels, about 1,000 feet in width. The distance from Sandy point across Bay St. George is 15 miles, and from The Gravels across Port au Port bay to Bluff-Head an additional 15 miles.

Bluff-Head is a bold headland of diorite, which rises vertically from the shore, about 2,000 feet. The country rock is diorite, traversed by frequent and broad belts of serpentine, of the dark green variety—at times almost black. The chromite, as in all other known deposits, is confined to the serpentine rocks, and the entire area in which the mineral has been discovered so far is controlled by the Halifax Chrome Co.

Seven exposures, ranging from 2 to 8 feet in width, were originally identified and sampled, but the work showed that what appeared at an intermediate point to be three separate bodies was really the outcrops of one body.

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[1] Mineral Ind., 1897, p. 149.

The analysis of samples from the different exposures gave a range of 39 to 50 per cent Cr_2O_3. The work was confined to the stripping of the surface, at the point where the outcrop measured 8 feet in width. After a relatively small amount of work, an exposure 97 feet in length, with a vertical face of 44 feet at the top by 46 feet on the bottom of the cutting, was made. The ore breaks out in large angular masses, the partings between the masses being thin bands of serpentine. Blocks of serpentine act as headers to the masses of chromite, but are readily separated by the blow of a sledge. In the blocks of massive chromite there are no intrusions of serpentine, other than the small granular particles which are pretty regularly distributed through the mass of chromite, and which will have to be removed by dressing in order to produce a marketable product of high grade.

From a report by Mr. C. E. Willis, it appears that on Mount Cormack, about 46 miles inland from Bay d'Espoir, chromite deposits of value exist. No further particulars are to hand, but it seems that the long distance from communication prevents—for the present at least—their exploitation.

The total quantity of ore mined from 1896 to 1899 was 5,500 tons. Most of this ore was shipped to Philadelphia, where it was sampled. A large quantity was used in the manufacture of furnace brick-lining. By close sorting and cobbing an effort was made to put a high grade of ore on the market, running over 50 per cent oxide of chromium, but the result was necessarily irregular. It was manifestly important not only to raise the grade, but also to secure regularity of the product, and this result can only be secured by a regularly organized dressing system. A test on 2237 kg. of this ore, made by Prof. R. H. Richards, gave 75·54 per cent of concentrates, assaying 55·30 per cent Cr_2O_3, and 24·45 per cent of tailings assaying less than 25 per cent Cr_2O_3. Subsequently concentration works were erected, but work has been going on very irregularly. No reports are to hand regarding operations for several years past.

CENTRAL AMERICA.

Chrome iron ore, apparently in abundant quantities, has been discovered near Antioquia, according to M. Boussignault, and it is said that the walls of some of the houses have been built with it. It is also reported that as far back as 1867 chromium pig iron was obtained from a blast furnace in the vicinity of Medellin.[1]

AUSTRIA.

Chromite occurs near Kraubath, in the Loeben district, but no work has been done there since 1881.

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[1] Hadfield, "Alloys of chromium and iron." Iron and Steel Inst., 1892, II, p. 64.

BOSNIA.

Chrome iron ore of good quality exists in Bosnia; and the Diosgyor works in Hungary have used this ore for basic linings in their steel furnaces. The shipments averaged 50 to 52 per cent Cr_2O_3; 39 to 45 per cent Al_2O_3 + Fe_2O_3, and 2·5 per cent silica, together with some lime and magnesia.[1]

GERMANY.

A large deposit of low grade chromite is found in Lower Silesia, on the southern slope of Mount Zobten, between Schweidnitz and Jordansmuehl. The ore body, which occurs in serpentine, was 23 feet thick near the surface, but it increased in magnitude as greater depth was gained. The composition of the ore is as follows: Cr_2O_3 35 to 42 per cent; Fe_2O_3 19 to 22 per cent; Al_2O_3 19 to 22 per cent; silica, 3 to 5 per cent; MgO, 16 to 18 per cent. Magnetite in variable quantities is mixed with the ore. The deposit, which was first mined in open workings, was exploited subsequently by a shaft and levels; but operations were not continued long, the material not being sufficiently refractory for use in basic-furnace hearths, and of inferior quality for the manufacture of bichromates.

Veins of chromite traversing serpentine are also known to exist in the vicinity of Frankenstein, in Upper Silesia, but attempts to work them have not proved remunerative.

GREECE.

Chromite is mined at Valos. The production varies from a few hundred to several thousand tons per annum, 10,750 tons having been mined in 1902. The ore, however, is low grade.

NORWAY.

Chrome iron ore is found at Drontheim, and at Roeraas. The production of the mines is small and irregular, not exceeding several hundred tons per annu.

RUSSIA.

Chrome iron ore is found particularly in the soapstones and serpentines of the Ural mountains. The principal localities are the banks of the Kamenka, and of the Topkaja.[2]

Gustave Rose classifies the Russian ores under three heads: (1) those which occur in large granular masses in serpentine in several places near Ekaterinburg, also eight miles from Bisserk, and again near Kyschtinsk;

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[1] Min. Ins., 1893, p. 156.

[2] Chemiker Zeitung, vol. xi, p. 53.

(2) those where the mineral is finely disseminated through the rock, as at Mostrowaia, north of Ekaterinburg, and near Auschkul lake; and (3) mineral found in the platinum and gold washings, especially at the platinum placers at Nizhnee-Taghilck and the gold placers at Malo-Mostowskoi. In Liberia at Orenburg the mineral is found in masses.

The manufacture of bichromates from the ore obtained in the Ural has been established in Russia through the efforts of M. Ushakoff, who built works for this purpose near Elabougi, on the river Kama. About 2,000 tons of ore are treated there yearly, and owing to the establishment of this industry the importation of chromium compounds into Russia has ceased.

Two analyses of ores are subjoined:—

Cr_2O_3	FeO	Al_2O_3	MgO	CaO	SiO_2
51·62%	17·94%	14·52%	13·15%	0·73%	1·71%
55·75	21·56	3·37	13·85	0·60	5·37

At the present time there are 50 chrome iron ore mines in the district, and their combined output is estimated at 1,600,000 poods (25,800 tons). The tendency of late years has been to increase the production. The price of the ore at Ekaterinburg is from 20 to 25 copecks (6d to 6½d) per pood (36 lbs.) with a 40-44 per cent content. In the year 1905 the Urals occupied the third position in the world as a chrome iron ore producer with 27,046 metric tons.

HUNGARY

Chrome iron ore occurs in Hungary in paying quantities at Orsova near the Danube. It is, however, mostly of low grade quality, and a shipment gave the following analysis: Cr_2O_3=38·95 per cent; FeO=16·13 per cent; SiO_2=8 per cent; Al_2O_3=17·50; CaO=2·2 per cent; MgO=17·2 per cent. The ore occurs in serpentine.

MACEDONIA.

A very good quality of chrome iron ore is mined near Monastir, the shipping port being Salonica. The mines have been considerably developed, but recent information regarding production could not be obtained.

NEW CALEDONIA.

Chromite was first discovered in New Caledonia in the year 1874. All the principal deposits are located among the mountains of the southern portion of the island, the containing rock being serpentine. When naturally broken *in situ*, chromite is known as alluvial chrome, and when massive it is termed rock chrome. The alluvial variety is mostly sought, as being in a more or less disintegrated and loose condition, but it is easier to mine than rock chrome, and requires no crushing previous to refining. A further advantage lies in the fact that the impurities adhering to the lumps are easily decomposed and rejected. According to F. D. Powers,[1] it is generally recognized by the miners that a dark serpentine, weathering with a bluish crust, is a favourable rock for chrome. To look at the large quarries and open-cuts left by the removal of the ore, one might be led to think that it occurs in isolated lenses, yet on closer examination it is found that the ore is continuous in depth, and at the ends is past the limits of the workings, only it is too poor, or the deposit too narrow, to pay for extraction. Taking a bird's-eye view of the several worked quarries, they appear to have the same general trend, and give the impression of being confined to certain belts. It is not actually established whether these lenses are in any way connected, but certain cases seem to point to such a connexion between the different ore bodies. The serpentine as a general rule occurs in bands, the longer axis of the chrome iron ore lenses corresponding with the general strike of these bands. The chromite does not occur in one solid mass, but is found in the joints of the serpentine. One may find grains of chromite disseminated through the serpentine, even outside the limits of the workable deposits. The ore itself does not shade off gradually into the serpentine, but shows a sharp line of demarcation.

From a paper read by M. Dupuy, before the Société de l'Industrie Minérale, August, 1906, it appears that chromite is found scattered in varying quantities throughout the mass of serpentine. The workable deposits are of two kinds. The first, like cobalt ore bodies, are found in extensive areas of ferruginous clay, forming a very rich, soft, and easily disintegrated ore; the other deposits occur as veins, or included masses, in the hard serpentine.

The early development of chrome iron ore was on a small scale, but since the formation of Le Chrome, this Company has obtained possession of all the deposits, controlling an area of 60,000 hectares, of which 6,000 hectares are held in concession, 6,000 more are applied for, and 48,000 are under exploration. The mineral areas are found in three different parts of the island. The largest is at the north, around the Tiebaghi mine, which yields an ore carrying up to 67 per cent sesquioxide of chromium. This mine produces between 4,000 and 5,000 tons of ore per month. The second group is situated at 20 km. to the south of Noumea, and contains the Lucky Hit mine. Here a chromiferous vein, having a width up to 15 m., is developed in depth, and forms the only chrome iron ore mine in the island that is developed below the surface. This ore, containing 30 to 40 per cent sesquioxide, is concentrated in a mill. The third group is situated in the south of the island and is not yet developed, although a railway has been built to it.

An idea of the size of chromite deposits in New Caledonia may be obtained when it is stated that over 20,000 tons have been extracted from one of the open-cuts. The Lucky Hit has yielded 13,000 tons; the Pensee 14,000 to 15,000 tons; the Josephine 18,000 tons; and the Alice Louise 10,000 tons.

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[1] Institution of Mining and Metallurgy, 1899–1900, p. [illegible]

With the exception of the mine Tiebaghi and the Lucky Hill, no serious development has taken place in chrome iron ore of late. The production for 1906 was 57,367 metric tons, as against 51,374 tons in 1905.

This industry is at present virtually in the hands of one firm. The value of chrome iron ore exported during 1906 is given at £98,671, that of 1905 at £88,363. New Caledonia supplies at present three-quarters of the world's demand. Of the 57,367 tons the Tiebaghi mines supplied more than 46,000 tons. Exports of chrome iron ore, according to the Bulletin of Commerce at Noumea, for the year 1907, amount to 25,372 tons.

Ore freight from New Caledonia to London via Sidney ranges from £1 5s. to £1 6s. per ton plus transhipment charges of 4s. per ton at Sidney. To the Continent by steamer via Sidney the rates are some 6s. higher. Coastal freights per sailer to Europe range from £1 3s. 6d. per ton for nickel and cobalt to £1 8s. per ton for chromite.

NEW SOUTH WALES.

The first attempt to mine chrome iron ore was made in 1882, when about 100 tons were extracted from the Bowling Alley Point deposits, near Peel river, but it was not until 1894 and 1895 that mining was seriously undertaken. About 2,000 tons were extracted and despatched at that time, from what is now known as the Vulcan mine.

The success which followed the opening of these mines drew attention to another group of chromite deposits in the neighbourhood of Mount Lightning. In consequence of the active operations which may be said to have commenced in that district in 1893, prospecting for chromite soon became general in all the serpentine belts known to exist in the various parts of the colony. The result was that chromite was found to occur in 62 different localities.[1]

TASMANIA.

According to R. A. Hadfield,[2] in the Ironstone hill near the river Tamar, at Port Lampiere, there are large deposits of brown hematite ore containing about 3 per cent of chromium sesquioxide, and but little sulphur and phosphorus. It is estimated that there are over 500,000 tons of such ore, large and small in boulders, in sight on the surface. The rocks of the district are contorted slates, sandstones, and limestones. In the immediate vicinity of the ore deposits there is a great mass of serpentine, containing many thin veins of asbestos and magnetite. In several of these rocks there are extensive outcrops of ironstone, protruding in great masses from the red surrounding soil, which has been obviously formed by their destruction, or there are heaps of ironstone boulders, of all sizes, formed from the disintegration of the beds.

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[1] Pittman, Mineral Resources of New South Wales, 1901; p. 285.
[2] Journal of the Iron and Steel Institute, 1892, No. 2, p. 65.

The geology of the district has been described by Mr. Gould, the Government Geologist, who considers the formation to be of Lower Silurian age. About 1872 the Tasmanian Iron and Charcoal Company, at Ilfracombe, near Launceston, smelted some of this ore in its blast furnaces, and produced an alloy containing 6 or 7 per cent chromium, of which several hundred tons were shipped to England.

ASIA MINOR.

This country has been for many years the most important producer of chromite in the world, having at Brusa (east of Constantinople) one of the largest known deposits of the mineral. It was discovered by Prof. Lawrence Smith, in 1848. Another large deposit, also discovered by Prof. Smith, exists at Harmanjick, about 15 miles north of Brusa, and there is a third one near Antioch. At each of these places the ore occurs in pockets and masses in serpentine, similar to those in California, but they are larger, and the ore is richer, averaging over 52 per cent Cr_2O_3. Owing chiefly to their softness, their richness in oxide of chromium, and their low silica contents, the Turkish ores have been in great demand, and for many years have constituted the principal source of supply of both American and European consumers. The mines are in the neighbourhood of Makri, and are practically a monopoly in the hands of one firm. The ore occurs here in serpentine, in the form of pockets and veins of very irregular extent and size.

South of Brusa, in the Province of Aidin, a great number of deposits occur, and Mr. W. F. A. Thomae[1] described them in a paper read at the Atlantic City meeting of the American Institute of Mining Engineers, of which the following is an abstract:

"The Villayet of Aidin is a province of Asia Minor, which has a coast line extending from opposite the island of Mytiline to beyond Makri, opposite the island of Rhodes, and embraces almost the entire basins of the two principal rivers, the Sarabat (Hermus) and the Mender (Maeander), besides some smaller ones. The principal town is Smyrna, the centre of trade of the district, from which two railways run into the interior along the valleys of the two rivers just mentioned.

"By far the greater part of this country is composed of limestones and schists, and presents a fine example of orthodox regional metamorphism. The shell, mud and other beds, originally deposited over a sea-bottom, extending probably far beyond the region here described, have been completely metamorphosed, the limestone to pure white saccharoid marble, now covering large areas, and the other beds, interstratified with it, to schists of various kinds - mica, chloritic and hydro-mica, often changing gradually the one into the other, and sometimes passing insensibly into gneiss. In several localities the schists contain regular octahedra of magnetite up to half an inch in diameter. In one place on the coast, a little below the island of Scios, pure red clay-slates occur, carrying thin beds of pyrolusite.

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[1] Min. Ins, 1897, p. 151.

"The general strike of these formations throughout the country is about east and west, though locally the schists are much folded, and strike and dip in all directions. The average dip is steep, but not uniform, and is not always apparent. South of Aidin it is generally south, while north of Aidin it appears to be to the north. Farther north again, at Odemish, the dip is south, indicating several parallel foldings of the strata, the number and extent of which, the observations made were not sufficient to determine.

"In several places serpentine belts occur. These appear to be interstratified with the marbles and schists, and would thus point to a result of the general metamorphosis on original possibly glauconitic deposits; but further investigation is necessary before it can be definitely asserted that they are not alteration products of intrusive sheets of basic olivine rocks. Round the Bay of Smyrna extensive areas consist of volcanic lavas and tuffs, chiefly trachyte. Overlying the metamorphosed formations there are found in places, such as between Suladan and Ala Shehr, and south of Chesme on the coast, undisturbed beds of sandstone, and soft, chalky limestone, lying flat or dipping at a very slight angle, and full of fossil shells, chiefly gasteropods."

A peculiar fact in connexion with the chrome iron ore deposits near Makri is that, they are richest near the surface, and that they invariably become poorer in depth. The concentration of low grade chrome iron ore will be a problem that will have to be faced in the near future, when the rich deposits become exhausted. When the industry was at its height over 30,000 tons of ore were exported per annum from Makri alone.

While Asia Minor formerly furnished the bulk of the supply of the world, adverse conditions have brought about a crisis, and the mines now produce little ore, the annual production having diminished to a few thousand tons only. New Caledonia takes now the place of the Turkish mines; transportation charges from this country to European and American ports are comparatively low, as the ore is taken in the majority of cases as ballast. And further, the inland roads in Asia Minor to the mines are mostly in a poor condition, making this part of the transport very costly indeed.

The ore is removed from the pit to the railway station, or market, on the backs of donkeys and camels, the surer footed donkeys being used in the higher altitudes, and the camels for the plains. This method usually involved two or three transfers between the point of origin and the port of Smyrna. It usually takes one donkey a week to carry 400 lbs. of chrome iron ore from the pits on the mountain tops to the camel stations below; it then takes five camels one day to transport a ton of chrome iron ore over a distance of 15 miles. The last shipment of chrome iron ore made from Smyrna was 1,500 tons in 1906. None of the mines have ever been worked with up-to-date machinery; besides these adverse conditions taxes are levied by the Turkish government on the total cost of the ore delivered on board ship. These taxes amount to 20 per cent on the value of the ore mined, and 1 per cent on the exports.

NEW ZEALAND.

Chrome iron ore occurs in New Zealand chiefly in association with the magnesian rocks of the Dun Mountain[1] mineral belt, in the Nelson district. With rocks of the same age and character it also occurs in northwest Otago and the southern part of Westland. In each locality the formation is of Devonian age. In the Nelson district chrome iron ore has been traced from D'Urville island, in the north, to the gorge of the Wairoa river. The chief developments of ore are found between the upper Maitai valley and the Lee river, a distance of 12 miles. The ore occurs in elliptical masses, some of which are of considerable size. The ore exported from Nelson has been mainly from one outcrop near Dun mountain, supplemented by a lesser quantity from Little Ben Nevis. Over this part the whole of the outcrops of value are held under lease, or the rights to mine have been otherwise acquired. The region lying between the Upper Wairoa and Tophouse, known as the Red hills, is composed, over a length of seven miles and a breadth of three miles, of olivine and serpentine rocks. This has not been explored or prospected, yet it is considered by the government geologist Mr A. McKay, to be a promising field for the occurrence of chrome or copper minerals. The Dun Mountain mineral belt, south of the Maitai valley, where the chief mineral belt lies, is rugged, mountainous country, and the position and amount of ore in each particular outcrop has to be considered carefully in relation to the cost of road-making, and carriage to Nelson. From the Red Hill area the distance is 15 miles to the railway at Moteuka crossing; to Blenheim the distance is more than 40 miles. In the southern area, extending from the neighbourhood of Jackson bay along the Chrome and Red Mountain ranges, and the mountains to the south as far as the source of the Greenstone river, there is a likelihood of the occurrence of chrome iron ore in quantity, but the character of the country is very rugged, and great cost in road-making would have to be incurred to bring to the sea-board any ores that might be found.

No chrome iron ore has been shipped from 1866 to 1900, when some work was done upon a deposit at Croixelles harbour and 28 tons were exported. During 1902, 175 tons, valued at £525, were exported; since that date all exports have ceased. The total exports of this ore since 1853 amount to 5,869 tons, valued at £38,002.[2]

INDIA.

Chromite occurs in the Pishin and Zhob districts. The chromite occurs as veins, and irregular, segregated masses in the serpentine that accompanies the great basic intrusions of upper Cretaceous age, which form particularly conspicuous masses amongst the hills bordering the Upper Zhob valley, both to the north and south. To the westward these serpentines continue into the upper valley of the Pishin river, which forms the geographical and geological continuation of the Upper Zhob, while to the east and northeast a few observations made at different times by various geologists, indicate their continuation at intervals along the Lower Zhob, and even as far as the Tochi valley.

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[1] Min. Ind., 1897, pp. 150 and 151.

[2] New Zealand Mines Record, 1907; Jan. 16.

One of the most promising localities occurs about 2 miles east of Khanozai, in the Pishin district, where Mr. Vredenburg specially investigated a vein-like mass about 400 feet long, with an average breadth of 5 feet. The vein consists of almost pure chrome iron ore of great richness. An analysis made in the laboratory of the Geological Survey gave over 54 per cent of chromium sesquioxide, and some parts of the vein show even a higher percentage. The locality is connected by an excellent road with Khanai railway station, 17 miles distant.

BELUCHISTAN.

Chrome iron ore was discovered in 1903. Since that time considerable exploration and development has been going on, and according to L'Echo des Mines, 19 small mines were in operation last year yielding an annual output of 7,000 tons.

RHODESIA.[1]

Chrome iron ore is now produced from large deposits in the neighbourhood of Selukrae. It is shipped to England and the continent via Beira, and brings £3 2s. 6d. per ton.

A sample of this ore sent to the Imperial Institute, London, by the British South African Company, gave the following analysis: Chromic oxide, 46·36 per cent; alumina, 13·18; ferrous and ferric oxides (calculated as FeO), 18·66; cobalt and nickel oxides, 0·17; magnesia, 13·64; silica, 4·58; water, 2·72. A fire assay of the sample showed a trace of platinum.

CUBA.[2]

A deposit near Canjete, on the north shore of Santiago de Cuba, has been reported upon. The ore is too low-grade to find employment in the steel industry, and its character is such as to preclude concentration.

TRANSVAAL.

In his review of the economic deposits of South Africa Dr. T. W. Voit[3] mentions the occurrence of chromite on the de Kroon farm, 20 miles west of Pretoria. The ore is found in the serpentinized pyroxenites, and contains

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[1] Min. Ind., 1906, p. 121.
[2] Ibid, 1904, p. 70.
[3] Zeitschrift fuer Praktische Geologie, May 1908, p. 192.

35·10 per cent chromic oxide (24·8 per cent chromium), and 11·35 per cent iron, also traces of platinum and gold. The concentration of this ore is difficult, hence its export is very unlikely.

According to Messrs. A. L. Hall and W. A. Humphrey[1] the first reference to an occurrence of chromite is found in the Report of the State Geologist for the year 1908, in which Prof. Molengraff mentions the presence of chrome iron ore as basic secretions in serpentinized norite northwest of M. Zilikat's Nek in Magaliesberg. Messrs. Hall and Humphrey divide the chromite occurrences of the Transvaal into two separate districts the Lydenburg and the Rustenberg districts. In the former, or in the eastern Transvaal, the belt of country rock in which the deposits are embedded is about 1½ miles wide, the deposits proper forming a more or less continuous chain of outcrops along the margin of the Bushveld plutonic complex. The ore occurs in 10 different localities, from the Steelpoort river northwestwards; the chromite zone lies between the magnetite horizon and the upper limit of the Pretoria series, and a typical coarse grained light coloured and mottled norite is either altogether absent or quite subordinate along the mineralized belt.

The ore occurs in fairly well defined bedded veins, with a dip and strike roughly analogous to that of the neighbouring sedimentary beds on the east, that is, about 8 to 15 degrees in a westerly or southwesterly direction. In thickness the veins range from 5 feet downwards, and usually maintain a fairly uniform width for some distance. While some outcrops may show one such ore sheet, others are made up of three to four in close proximity to each other. That the above-mentioned occurrences represent probably detached outcrops of a more connected system of veins is rendered likely by the ease with which the veins can be followed along the strike, especially when the distribution of the above-mentioned dark coloured indicator is noted. In this respect the ore sheets seem to resemble the bedded sedimentary rocks; although in view of their mode of origin and their essentially igneous character, prolonged continuity would scarcely be natural.

In the Rustenberg district, or in the central and western Transvaal, chromite deposits occur along a more or less well defined zone situated at an average distance of 5½ miles north and northeast of the crest line of the Magaliesberg range, and extending over a length of about 28 miles from a short distance northwest of Rustenberg, through the farm Kronendaal as far eastwards as the Crocodile river. About 12 localities are named, where chromite is found. One of these deposits, which is typical of all the others, forms a well defined bar about 10 yards wide on the surface, composed of dark, hard, rather compact, lustrous chromite, showing a slight tendency to banding on the weathered surface.

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[1] Transactions of the Geological Society of South Africa., vol. xi, May 18, 1908.

Another occurrence, that on Kronendaal, forms one of several distinct outcrops. The following downward succession of rocks is observed:

(*a*.) Dark greyish black, fine chromite sand.
(*b*.) Fine grained norite, 4 inches.
(*c*.) Soft friable fine grained chromite, 7 inches.
(*d*.) Norite similar to (b), 2 miles.
(*e*.) Chrome iron ore veins resembling (c), 12 inches.
(*f*.) Norite similar to (b).

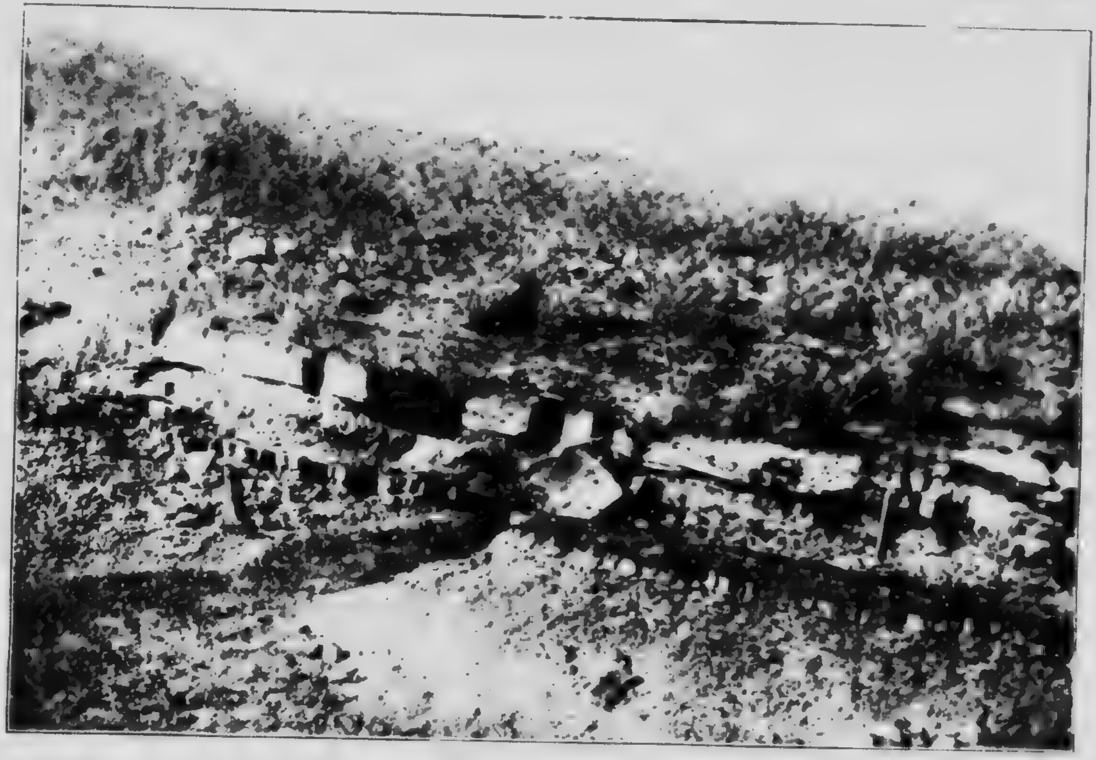
In the accompanying plate No. XI—which is herewith presented through the courtesy of Messrs. Hall and Humphrey of the Geological Society of South Africa—the shorter hammer on the right rests against the upper vein (e); while in the foreground on the left the larger hammer lies on the lower vein (c). Both veins have a well defined dip of about 10 to 12 degrees, and are sharply defined against the country rock, which consists of fine grained norite rich in pyroxene.

The Transvaal ore consists of a black, lustrous, fine grained aggregate of granular chromite, which easily weathers to a friable rock and becomes readily disintegrated into sand. In several localities, however, the ore becomes hard and compact, and may show on the weathered surface an alternating series of lighter and darker coloured bands, due to the development of some zones containing less basic constituents. As the ore becomes less pure, more ferro magnesian constituents appear, and a gradual transition from heavy black chromite ore to a less heavy and dark coloured hypersthenite, or enstatite, takes place. The following analyses of ore from three locations are given:

	I	II	III
Cr_2O_3	36·16%	35·30%	37·03%
Fe	41·35	.....	.....
FeO	....	19·60	23·95
Fe_2O_3	.....	2·10	0·71
MgO	5·91	13·45	9·94
Al_2O_3	9·26	13·70	17·23
SiO_2	3·08	12·70	7·63
CaO	2·10	2·05	2·00
Pt	Trace	.....	.....
MnO_2	...	0·80	1·16
H_2SO_4	....	.....	.....
H_3PO_4	...	0·15	0·17
H_2O	....	0·08	0·13
	97·86	99·93	99·95

These analyses show that the content of chromium sesquioxide is not sufficient to allow of the introduction of the Transvaal ore on the world's market. However, as prospecting has been done for this ore in a very superficial way, it is yet possible that ore of a higher tenor may be found.

PLATE XI



Veins of Chrome Iron Ore. Kronendaal near Rustenburg, Transvaal.
Reproduced through courtesy of Messrs. A. L. Hall and W. A. Humphrey
members of the Geological Society of South Africa

CHAPTER VIII.

ORIGIN.

From the description of the chromite deposits in the foregoing chapters we learn that chromite occurs in peridotite (as in North Carolina), and in serpentine (as in Canada), the derivative of peridotite. As to the occurrence of chromite in peridotite—the original (olivine) rock—quite extensive investigations have been made by Mr. Hyde Pratt in the peridotites in North Carolina.[1] In the following, a résumé of his theories—based on practical investigations—is given:

"The large deposits of chromite in North Carolina occur in peridotite, near the contact of this rock with the enclosing gneiss, and where there is but a small amount of chromite, either in pockets or in grains or crystals. These are more abundant near the contact and diminish in numbers towards the centre of the mass of peridotite. The constant occurrence of the chromite in rounded masses, of varying size, near the contact of the gneiss with the peridotite in the fresh as well as in the altered peridotite, clearly indicates that the chromite ore was held in solution during the intrusion of the peridotite, and that it collected and separated out during the subsequent long process of cooling. It is quite evident that the peridotite magma, which held the chemical elements of the various minerals in solution, presented a saturated liquid, and during the process of cooling and solidification the minerals would crystallize out according to their solubility in the mother magma. These would be the oxides containing no silica in the present case chromite. It is very probable that the latter would solidify or crystallize out first, where the magma began to cool, that is near the contact with the gneiss. The more fluid a molten mass of rock becomes the more favourable will be the conditions for rapid and effectual connexion, and it is in these very basic magnesian rocks that we find the best illustrations of the separation and concentration of the more basic minerals. The longer the chromite remained in solution the less opportunity there would be for it to separate out in sharp distinct masses, and as the molten magma began to lose some of its fluidity, it would tend to separate out in smaller bunches, or in grains scattered through the peridotite."

As to the New Caledonia deposits, which occur in serpentine, Mr. Danvers Power[2] finds that the grains of chromite occur all through the serpentine, even outside the limits of the workable deposits: the ore itself does not shade off gradually in the serpentine, but shows a sharp line of demarcation. Mr.

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[1] Corundum and the Peridotites in North Carolina. North Carolina Geol. Survey, 1905, vol. i, p. 369.

[2] Inst. Mining and Metall., 1899–1900, p. 444.

Power argues in the following way: If this chromite was due to differentiation in the molten magma, one would expect the ore to pass gradually from rich to poor, and thence insensibly into serpentine; instead of this, however, we find it occupying joints which could not have existed until the rock had solidified. That chromium in the form of chromite or picotite was an original constituent of the eruptive rock is shown by microscopic slides which give examples of ores of these minerals—which one it is difficult to determine—partly in olivine and partly in serpentine due to the alteration of olivine, the chrome-bearing grain itself showing no signs of alteration. That it is difficult to satisfactorily demonstrate how the chromite got transferred to joints, considering its difficultly soluble nature, we admit; still we find the chrome iron ore occupying natural water channels in the rock, sometimes with a thin coating of chrome ochre, showing that there is still some natural agent in force which is capable of decomposing the chromite. Both chromite and picotite vary considerably in the proportions of their constituents, as the following limits obtained from several analyses from various parts of the world show:—

	Alumina	Ferric oxide	Magnesia	Silica	Oxide of Chromim
	per cent	per cent	per cent	per cent	per cent
Picotite....................	55·00	3·21	10·23	0·20	7·80
Chromite	0·19	18·38	0·18	0·10	39·66

From the above it would appear as if chromite, which is isomorphous with chrome spinel, might have been formed from it.

Messrs. A. L. Hall and W. A. Humphrey, who closely studied the chromite deposits of the Transvaal (see page 83) came to the following conclusion as regards the origin of the ore:—

"In all the thin sections examined the chromite is found in small well-defined grains, possessing very good crystal outlines, and this evidently points to the conclusion that the ore particles were among the first constituents to crystallize out. The same also holds good in those cases where the grains apparently envelop large crystals of enstatite or hypersthene, and wrapped round them to produce a kind of net-work resembling the well-known mesh structure seen in highly serpentinized olivine rocks; for although such an appearance seems to indicate that the central rhombic pyroxene belongs to a phase of crystallization preceding that of the granular chromite, one frequently finds along the edge of the former some of the grains of the ore partially surrounded by enstatite and lying in a little indentation running into the latter. Since these two minerals constitute practically the entire rock, the residual mother-liquor left after the separation of the chromite must have had a composition agreeing closely with that of the particular rhombic pyroxene met with, so that finally the magma would consolidate as a whole, thus producing the rude kind of cellular structure alluded to.

"The gradual though rapid transition from the purer ore, within the veins, to an enstatite rock, or hypersthenite, still containing a fair amount of chromite, but with a much larger proportion of feldspathic material, as well as the absence of a sharp line of division between ore and country rock, clearly points to the conclusion that these deposits are of igneous origin, and must be regarded as due to local concentration of scattered chromite grains as one of the factors in the differentiation of the magma of the Bushveld plutonic complex.

"The mode of origin of these chromite deposits is, therefore, similar to that of numerous occurrences associated with basic igneous rocks in other countries."[1]

As to the Canadian chromite deposits, it is quite evident that according to microscopical investigations the present serpentine is a derivative from olivine or peridotite, the dehydrated magnesian rock. The formation of chromite is explained by the oxidation of chromium which is supposed to have been originally present in the rock – to chromic oxide, and the association of the latter with iron protoxide, which had also been formed through the oxidation of the iron which formed an accessory mineral of the rock. Of course the actual formation of chromite must have been effected during the cooling or solidification of the magma under conditions which cannot be sufficiently explained; pressure and different temperatures very likely have facilitated these transformations; at any rate it is quite certain that according to the law of solubility chromite must have crystallized first out of the magma, and this crystallization or accumulation was apparently greatest where the cooling was quickest; that is, at the contact of the serpentine with some other rock. This does not mean, however, that chromite is mostly found close to the contact of serpentine with the country rock through which the original peridotite penetrated, for we find to-day excellent chromite deposits away from such contacts. It is evident also that the manner in which the crystallization or accumulation in different parts of the serpentine took place is responsible for the great irregularity of the deposits, the pockety nature and the lack of connexion between the deposits, and also for the disseminated form in which the ore occurs. These irregularities were further accentuated through the shifting and displacement through which the rock had to pass after the deposition of the mineral, for we observe that the ore bodies sometimes are abruptly cut off and displaced through slickensides.

Much has been done in the way of microscopic investigations as regards the transformation of the original olivine or peridotite into serpentine; but few geologists and petrographers have taken up the study of the phases through which chromite had to pass until it constituted the present mineral. It is to be hoped that this subject will be treated in the research laboratory, as the observations in the field alone are insufficient for a complete study of the origin of this mineral and the conditions under which it was formed.

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[1] See I. H. L. Vogt: "Beitr. zur genet. Classification, etc.," "Zeitschr f. Prakt. Geol.," 1894, p. 381.

CHAPTER IX.

COMPOSITION OF CHROME IRON ORES.

Pure chromite contains 68 per cent oxide of chromium, Cr_2O_3, and 32 per cent protoxide of iron, FeO.

But all chromites found in nature contain almost invariably foreign rock matter. The usual impurities are silica, magnesia, and alumina. The ore for market purposes is required to reach at least 50 per cent, but it is usual to dress the lower grades up, either by hand cobbing or by mechanical means, to 52 per cent, so as to be on the safe side and allow a little for differences in sampling and assaying. The percentage of metallic iron and silica is also important, as generally not more than 10 per cent of the former, and from 8 to 11 per cent of the latter is admitted. In the use of chromite for the production of chromium salts the cost of treating low and high grade ores is the same, but there is a decided difference in the quantity of the finished product, so that unless the smaller initial cost of the low grade ore will counterbalance the value of this difference of the finished product, its use is unprofitable. These factors, therefore, fix the price of low grade ore, and circumstances such as labour and cost of equipment will determine whether it can be worked at a profit or not.

As to the composition of the Canadian chrome iron ores all the analyses subjoined hereto show that the principal constituents, apart from the chromic acid, are protoxide of iron, alumina, silica, and magnesia, while the contents of lime, in the majority of cases, remain below one-half per cent.

In the run of mine ore the protoxide of iron varies roughly between 11 and 22 per cent, alumina between 4 and 14 per cent, silica between 2 and 20 per cent, and magnesia between 4 and 16 per cent. Mechanical separation such as is carried on in the Eastern townships, now increases in the low grade ores the percentage of chromic oxide almost entirely at the cost of alumina, silica, and magnesia, so that the final result of the concentration is a shipping ore high in chromic oxide and comparatively low in the above-mentioned impurities, the greater part of the latter being found in the tailings.

Wm. Glenn[1] cites the following three analyses as typical of the run of the commercial product, the sources of the ore not being given:

SiO_2	7·00	5·22	6·44
Cr_2O_3	39·15	51·03	53·07
FeO	27·12	13·06	15·27
MgO	16·11	16·32	16·08
CaO	3·41	2·61	1·20
Al_2O_3	7·00	12·16	8·01
	99·79	100·40	100·07

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[1] Seventeenth Ann. Rept., U.S. Geol. Survey, 1895–6, p. 5, iii, p. 264.

Mr. Glenn adds the following remarks:

"It will be observed that ores have from 5 per cent to 7 per cent of silica, rarely less and not often more. It is unusual to find consignments of ore as low as 7 per cent alumina; it is not unusual to find them containing twice that quantity. Apparently these are the elements which mostly interest metallurgists. As to chromic oxide, that represented by the first analysis would be regarded as very poor, the second sample as rich, and the third as very rich. The greater part of chrome iron ore now being offered in the market varies between 40 per cent and 46 per cent chromic oxide."

The chromite in meteorites is very generally supposed to be nearly pure FeO, Cr_2O_3, but only one analysis has so far been made of meteoric chromite, and that is the one made by Lawrence Smith[1] upon chromite found in one of the Butcher meteorites from Coahuila. This analysis gave Cr_2O_3 62·71 per cent, FeO 33·83 per cent, with traces of magnesia, cobalt, and silica. Dr. Smith says: "The magnesia and silica doubtless come from a siliceous mineral observed to be intimately associated with the chromite, which is either enstatite or olivine."

Pratt[2] speaks of the composition of terrestrial chromite as follows:

"In all the terrestrial chromite analyses, with the exception of two, alumina and magnesia were invariably present, varying from a small percentage in some analyses to more than 20 per cent in others. As a general rule the contents of alumina varied with the magnesia; those rich in magnesia being correspondingly ric [illegible] na. This constant occurrence of these two constituents seems to indicat [illegible] combination of three isomorphous molecules, FeO, Cr_2O_3; MgO, Cr_2O_3, and MgO, Cr_2O_4. Only two analyses have been found so far that do not show the presence of magnesia and alumina. One was a magnetic chrome sand from Chester, Pa., analysed by T. H. Garrett, in which all the iron is calculated as ferric oxide; the other one, chromite from Vache island, West Indies, analysed by I. Clouet.

	1 (Garrett)	2 (Clouet)
Cr_2O_3	41·55	51·53
FeO	....	48·46
Fe_2O_3	62·02	..
SiO_2	1·25	...
	104·82	99·99

The general results of over one hundred analyses of ore found in California may be given as follows:

Del Norte county	39 to 45	per cent	Cr_2O_3
Napa county	42 to 46	"	"
Placer county	35 to 55	"	"
Tuolumne county	44 to 45	"	"
San Luis Obispo county	38 to 60	"	"
El Dorado county	20	"	"

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[1] Amer. Journal Sci., 1881, p. 462.

[2] T. H. Pratt, Trans. Am. Inst. M. E., 1899, p. 32.

COMPOSITION OF CANADIAN ORES.

Locality	Oxide of chromium Cr_2O_3	Protoxide of iron FeO	Alumina Al_2O_3	Silica SiO_2	Magnesia MgO	Lime CaO	Sulphur	Moisture	Total	Authority
Bolton, Que.	45·90	35·68	3·20		15·03				99·81	Geol. Sur Rept. 1863, p.504.
Lake Memphremagog.	49·75	21·28	11·30		18·13				100·46	" " " "
Coleraine.	52·82									" " 1894, p. 67 R.
Lot 17, R. iv, Thetford.	35·46									" " 1887-8, part ii, 56 T.
Source not given	39·15	27·12	7·00	7·00	16·11	3·41			99·79	XVII Annual Rept., U.S. Geol Survey, part. iii, p. 263.
" "	51·03	13·06	12·16	5·22	16·32	2·61			100·40	
" "	53·07	15·27	18·01	6·44	16·08	1·20			100·07	
" "	50·65	13·93	12·70	3·35	15·04				95·67	Min. Indus. 1895, p. 101.
Coleraine Mfg. Co.	58·06	21·70		1·60			0·057			Pittsburgh testing laboratory—
Ireland (King Bros).	60·21	14·41	7·89	0·40	15·50	1·46		0·15	100·00	Obalski, 1898, p. 6.
" "	56·14	14·86	8·71	2·98	15·69	0·70		0·09	100·00	Dr. Milton S. Hersey, Montreal.
Coleraine B.	47·69	14·33	18·31	4·70	14·47	0·50			100·00	
Coleraine Mfg. Co., No. 1 crude ore	51·06	13·63	14·66	4·18	14·20	2·27				
No. 2 "	45·26	12·72	16·80	4·61	18·27	2·34				
No. 3 "	40·12	11·20	18·63	4·87	22·52	2·65				
Concentrates.	53·64	11·47	14·02	2·31	15·75	2·81				Sent to Paris Exposition by the Coleraine Mining Company.
Tailings.	2·86	traces	32·55	16·15	45·26	4·18				
Slime	1·27	traces	31·33	17·03	46·16	4·24				
Black Lake, Chrome & Abestos Co. Concentrates	50·35	17·77	9·90	3·10	16·02	1·80		1·06		Obalski's Rept. 1903, p. 15
Black Lake Chrome & Asbestos Co. Pit 1	51·18	19·80	11·35	7·48	2·62	0·40				H. A. Leverin, analyst to the Mines Branch.
Same	43·57	17·61	13·90	12·62	3·83	0·20				
Montreal pit of the Black Lake Chrome & Asbestos Co., crude ore	43·24	17·74	7·12	8·62	4·00	14·17*				" " " "
Canadian Chrome Co., lot 16, range A, Coleraine, crude ore	45·95	22·50	8·90	7·68	4·90	0·12				" " " "
American Chrome Co., disseminated ore from lots 6 and 7, R. B, Coleraine	2·76	12·47	6·90	27·48	20·90	0·90*				" " " "
Lot 5, X, 19, Coleraine, crude ore	43·44	19·42	6·45	11·28	6·50	0·12				" " " "
Lot 5, range iv, Coleraine; disseminated ore.	18·57	15·30	4·79	25·22	24·72	0·10				" " " "
Lot 28, range ii; Ireland, crude ore	45·87	16·32	12·39	6·64	6·20	0·15				" " " "
Lots 36 and 37, range v, Garthby, disseminated ore	23·27	15·20	6·52	21·30	17·75	0·10*				" " " "
Lots 36 and 37, range v, Garthby, disseminated ore.	27·55	15·82	8·10	20·76	12·96	0·10*				" " " "
King Bros., Black lake; exact locality not given; average of 50 lb. bags	53·58	21·53	7·56	1·30	13·69	1·30	1·04			Dr. Milton S. Hersey.
Same	54·18	21·81	4·74	1·00	13·75	3·60	0·62			" " "
Carefully selected crystals.	58·09	21·20	5·64	0·96	11·26	2·75	traces			" " "

not given; average of 50 lb. bags	53·58	21·53	7·56	1·30	13·69	1·30	1·04	Dr. Milton S. Hersey.
Same	51·48	21·81	4·74	1·00	13·75	3·60	0·62	" " "
Carefully selected crystals	58·09	21·20	5·64	0·96	11·26	2·75	traces	" " "

COMPOSITION OF FOREIGN ORES

Locality	Cr_2O_3	FeO	Al_2O_3	SiO_2	MgO	CaO	H_2O	MnO	Total	Authority
Asia Minor—										
13 Brusa	55·04	12·63	11·84	2·00	16·19	1·46	0·40		99·86	Mr. Shaw, (Min. Ind., 1893, p. 155).
14 "	51·70	14·20	14·10	3·50	14·30	1·70	0·30		99·80	" " " "
15 "	56·80	12·06	14·00	1·45	15·00	0·70	0·15		100·16	" " " "
"	55·04	12·63	11·84	2·00	16·49	1·46	0·40			Dr. Milton Hersey, Montreal.
"	51·70	14·20	14·10	3·50	14·30	1·70	0·30			" " "
"	56·80	12·08	14·00	1·45	15·00	0·70	0·15			" " "
Karahissar	53·00	24·92	7·62	2·15	12·31					A. Clouet in *l'Industrie.*
Newfoundland—										
Bluff-Head, Port au Port bay	49·23	17·21	7·50	6·51	18·66				99·11	Dr. Elwyn Waller, (Min. Ind., 1897, p. 149).
New Caledonia—	39·66	18·38	0·19	0·10	....					Danvers Towers, Inst. of Min. and Metall. 1899-1900, p. 440.
	42·60	37·20 Fe_2O_3	12·80	1·20	5·10		1·10		100·00	Jules Garnier, Memoires de la société des Ingénieurs Civils, vol. XL, p. 244-266.
	41·80	19·02 "	29·10	2·10	5·10	....	3·40		100·52	
Russia—										
Ural.	51·62	17·94	14·52	1·71	13·15	0·73				W. Venator and E. Etienne (Min. Ind., 1893, p. 157.)
Ural.	55·75	21·56	3·37	5·37	13·85	0·60				
Ekaterinburg	49·49	23·27	6·77	7·07	13·40					A. Clouet, in *l'Industrie.*
Orenbourg.	53·00	24·92	8·05	3·05	10·98					
Viatka.	58·00	18·18	10·00	2·20	11·62					
Hungary—										
Orsova.	38·95	16·13	17·50	8·00	17·2	2·2				A. Go..zy, Stahl and Eisen, vol. IX, p. 729.
Orsov	31·48	29·60	16·77	7·30	14·85					A. Clouet in *l'Industrie.*
Orsova.	48·72	18·33	12·60	5·26	15·09					" " "
Servia: near Jelica Plenina.	52·46	15·26	14·01	10·15	7·62	0·98				A. E. Glasser, Annales des Mines, vol. V, p. 69-110.
Germany										
Lower Silesia, Mount Zobten.	35 42	19 ·22 Fe_2O_3		3 – 5	16 18					Stahl and Eisen, vol. X, p. 1085
Norway—										
(Christiania)	40·00	37·77	4·80	4·20	13·23					A. Clouet, *l'Industrie.*
Drontheim.	42·00	19·72	12·00	5·00	21·28					" "
France—locality not specified	37·00	34·79	13·15	2·53	12·53					" "
Styria	53·00	24·92	8·00	2·50	11·58					" "
India: locality not specified.	47·50	35·70	9·30	1·50	6·00					" "
Shetland Islands—										
I.	44·20	24·93	7·47	6·10	17·30					" "
II.	41·00	23·14	10·15	8·85	16·86					" "
California, U.S.—										
1. San Luis Obispo county	43·70	14·80	15·96	7·96	16·49	0·66	0·49		100·06	H. G. Shaw, San Francisco, Cal. (Min. Ind., 1893, p. 153.)
2. "	52·70	14·20	12·50	4·00	15·50	0·40	0·50		99·80	
3. "	40·00	14·20	22·00	6·10	16·80	0·70	0·3		100·10	
4. Tehama county.	34·46	14·16	19·00	10·96	20·50	0·80	0·2		100·13	
5. Alameda county.	46·00	16·00	14·00	7·40	15·70	0·50	0·29		99·89	
6. Shasta county.	42·45	15·00	16·75	7·50	16·50	0·90	0·80		99·20	
7. Del Norte county.	47·29	14·00	15·23	5·90	16·56	0·75	0·45		100·15	
8. San Luis Obispo co., concentrator	52·86	15·45	11·59	3·00	16·26	0·76	0·10		100·02	
" crude ore	43·70	14·00	15·96	7·96	16·49	0·66	0·49		100·06	
North Carolina—										
Price creek	59·20	25·02	7·15	3·20	4·42			0·92	99·91	Dr. C. Baskerville, University of N. Carolina.
Corundum hill.	57·20	25·68	7·82	2·80	5·22			0·69	99·41	" " " "
Locality not named.										
Pennsylvania: Chester	21·67	21·81	10·50	19·60	19·76	3·00	3·66			Dr. Milton Hersey, Montreal.
Cuba—	41·55	62·02 Fe_2O_3	..	1·25	...				104·82	T. H. Garrett.
Typical analyses of consignments of chrome ore. Baltimore Chrome Works.	50·00	18·57	12·44	3·82	13·38	2·16				U.S. Min. Res., 1904, p. 325.
	39·15	27·12	7·00	7·00	16·11	3·41				
	51·03	13·06	12·16	5·22	16·32	2·61				William Glenn, Baltimore.
	53·07	15·27	8·01	6·44	16·08	1·20				

1, 2, 3, 4, 5, 6, 7 average analyses of typical California chrome ores;
8 analysis of concentrator from crude ore under No. 9.

CHAPTER X.

STATISTICS AND CHRONOLOGY.

PRODUCTION AND EXPORT OF CANADIAN CHROMITE.

ANNUAL PRODUCTION (Geological Survey)

Calendar Year	Tons (2,000 lbs.)	Average price per ton.	Value
1886	60	$15.75	$ 945
1887	38	15.00	570
1888 to 1893	no output	.....	......
1894	1,000	20.00	20,000
1895	3,177	13.00	41,300
1896	2,342	11.53	27,004
1897	2,637	12.31	32,474
1898	2,021	12.00	24,252
1899	2,010	10.86	21,842
1900	2,335	11.56	27,000
1901	1,274	13.14	16,744
1902	900	14.44	13,000
1903	3,509	14.57	51,129
1904	6,074		67,146
1905	8,575		93,301
1906	8,750		92,100
1907	7,196		72,901
1908	7,225		82,008
	Total value		$683,716

Mr. Obalski gives for the years 1904, 1905, 1906, 1907 and 1908 the following figures:--

Year 1904.

1st class in rock	616 long tons, worth	$ 8,193
2nd class in rock	1,102 " " "	11,020
Concentrate	4,022 " " "	52,286
Total	5,740	$71,499

Year 1905.

1st class in rock	837 tons, worth	$ 10,450
2nd class in rock	3,406 " "	30,654
Concentrate	4,285 " "	63,461
Total	8,528	$104,565

Year 1906.

1st class in rock	.. 417 tons, worth...	$ 4,743
2nd class in rock	..4,054 " " ..	34,375
Concentrate.	.....4,490 " " ...	52,716
Total	8,961	$91,834

Year 1907.

1st class in rock	.. 145 tons, worth...	$ 1,925
2nd class in rock	..3,536 " "	33,485
Concentrate..	....2,040 " " ...	27,720
Total	5,721	$63,130

Year 1908.

1st and 2nd class in rock	..3,754 tons, worth ..	.$38,740
Concentrate	.............3,000 " "	45,000
	6,754	$83,740

According to the foregoing statistics the mines have produced during a period of 4 years, for 1904, 1905, 1906, and 1907, the following quantities and percentages of the different grades:

Quantity	Grade	Per cent	
2,015 long tons	No. I crude, or	6·9	per cent of the total production.
12,098 long tons	No. II crude, or	41·8	" "
14,837 long tons	concentrates or	51·3	" "
28,950 long tons		100.0	

Statement showing amount of Canadian Chromite exported from Canada during Calendar years 1903 to 1908, and four months of 1909, as compiled from the monthly reports of Trade and Navigation:—

CALENDAR YEARS	TO GREAT BRITAIN		TO UNITED STATES		TO OTHER COUNTRIES		TOTAL EXPORTS	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
		$		$		$		$
1903	62	4,650	914	15,319	37	555	1,013	20,524
1904	192	11,395	2,859	45,649	287	3,292	3,338	60,336
1905	153	11,030	1,966	23,362	—	—	2,119	34,392
1906	—	—	891	10,188	—	—	891	10,188
1907	108	10,400	784	9,400	—	—	892	19,800
1908	—	—	4,571	56,864	—	—	4,571	56,864
1909 (4 Mos.)	—	—	908	11,146	—	—	908	11,146

Tons = 2,000 lbs.

NOTE.—It will be observed that the exports to Great Britain average in value from $60 to $96 per ton, while those to the United States range between $11 and $16 per ton, and it may be inferred that the exports to Great Britain possibly represent ferro-chrome which may have been entered with the chromite by the Customs officers in the absence of a more definite classification.

UNITED STATES

PRODUCTION, IMPORTS AND CONSUMPTION.

Year	Production			Imports			Consumption	
	Quantity long tons	Value per ton	Value	Quantity	Value per ton	Value	Quantity long tons	Value
		$	$		$	$		$
1898	100	10.00	1,000					
1899	100	10.00	1,000	16,304	16 70	272,234	16,404	273,234
1900	nil			15,793	18 03	284,825	15,803	285,825
1901	498	15.54	7,740	17,542	17 39	305,001	17,542	305,001
1902	315	15 00	4,725	20,112	18 05	363,108	20,480	368,898
1903	150	15 00	2,250	39,570	14 73	582,597	39,885	587,322
1904	123	15 00	1,845	22,931	13 13	302,025	23,081	304,275
1905	40	15 00	600	24,227	14 38	348,527	24,350	350,372
1906	180	10 00	1,800	54,434	13 32	725,301	54,874	725,901
1907	355	15.00	5,620	43,441	12 84	557,594	43,621	559,394

THE WORLD'S PRODUCTION OF CHROMITE, IN METRIC TONS.

Year	Bosnia	Greece		New Caledonia		New-foundl'd	New South Wales		Russia		Turkey		United States		Canada		India	
	tons	tons	value	tons	value	tons	tons	value	tons	value	tons	value	tons	value	tons	value	tons	value
			■					$		$		$		$		$		$
1897.	396	563	18,000	3,949	....	3,084	3,433	51,345	13,433	32,804	11,551	....			2,637*d*	32,474		
1998.	458	1,367	55,310	7,712	....	657	2,145	31,505	15,467	37,600	■	....			2,021*d*	24,252		
1899.	200	4,386	70,200	12,634	....	717	5,327	87,080	19,146	46,742	4,538*b*	....			2,010*d*	21,842		
1900.	100	5,600	47,700	10,474	....	....	3,338	59,135	18,234	....	9,749*b*		142		2,335*d*	27,000		
1901.		4,580	140,160	17,451	....	....	2,523	38,870	....		40,972*c*	481,421	132	....	1,274*d*	16,744		
1902.	270	11,680	....	10,281	....	....	454		19,655	....	*a*		315	4,725	900*d*	13,000		
1903.	147	8,478	....	21,437	....	....	1,982		■	....	*a*		150	2,250	3,509*d*	51,129	260	
1904.	279	15,430	....	42,197	....	....	403		■		*a*		123	1,845	5,740*d*	71,499	3,654	
1905.	186	8,900	....	51,374	£88,363	....	53		27,046		*c*		40	600	8,528*d*	104,565	2,751	17,410
1906.	320	11,530	....	57,367	£98,671		15		*a*		*a*		317	2,859	8,961*d*	91,834	4,445	35,940
1907.	*a*	*a*	*a*	31,552	$277,657		30		*a*	....	*a*		355	5,620	5,721*d*	63,130	*a*	*a*
1908.	*a*	12,430	92,582	29,818	$233,637	*a*			25,800	206,400	*a*		280	5,600	7,225	82,008	7,000	56,000

a. Statistics not available. *b*. Exports from Salonica and Smyrna. *c*. Exports from European and Asiatic provinces *d*. Short tons
The world's production for 1906 is placed at about 100,000 tons, valued at approximately $950,000

Chronology of the Chrome Industry

The following table will demonstrate the development of the chrome industry since the discovery of the metal chromium up to the present time.

Year	
1762.	First attention drawn to a new mineral from Siberia, now called crocoite (chromate of lead, Dana).
1786.	Analyses of this mineral by Lehmann, but no discovery of chromium.
1789.	Analyses of this mineral by Macquart and Vauquelin. Suspicion as to presence of foreign element expressed.
1797.	Discovery of the element chromium by Vauquelin in crocoite.
1798.	First discovery of chrome iron ore in the Urals by Soymonof.
1810–15.	Successful manufacture of chrome salts.
1820.	Application of chrome salts to dyeing turkey red, by Koechlin. Application to dyeing of textile fabrics and to decoration of porcelain.
1823.	Discovery of chrome iron ore in the Bare hills, Baltimore county, Maryland, U.S.A., by Isaac Tyson.
1825.	First shipment of American chrome iron ore to England.
1827.	Discovery of large chrome iron ore deposits in Harford county, Maryland, U.S.A.
1828.	Discovery of the famous Wood Farm deposit, Lancaster county, Pennsylvania, U.S.A. The output up to 1894 amounted to 95,000 tons of ore.
1828–30.	First factory for the manufacture of chromic acid salts in Europe, by J. and T. White, in Glasgow, Scotland.
1845.	First factory for the manufacture of chromic acid salts in America, by Mr. Tyson, in Baltimore.
1847–48.	First reference to occurrence of chrome iron ore in Bolton, Eastern townships of the Province of Quebec, in the reports of Geol. Survey of Canada for 1847–48.
1848.	Discovery of large deposits of chrome iron ore near Brusa, Asia Minor (fifty-seven miles east from Constantinople), by Prof. I. Lawrence Smith.
1850.	First large exportation of chrome iron ore from Brusa, Asia Minor, affecting the world's market.
1853.	Discovery of chromite in New Zealand.
1856.	First application of chromium compounds to tanning leather.
1858.	Discovery of chromite in Mount Albert, Gaspé peninsula, Canada, by members of the Geol. Survey.
1863.	First exploration of chrome iron ore deposits in the neighbourhood of Lake Nicolet, in the Eastern townships, Province of Quebec, Canada.
1869.	Discovery of chrome iron ore deposits in the mountains of Santa Lucia, in the northwestern portion of the county of San Luis Obispo, California.

Year.	
1870.	First discovery of chromite in Del Norte, Sonoma, and Placer counties, California.
1874.	Discovery of chrome iron ore in New Caledonia.
1881.	First manufacture of chrome-steel armour plates in France.
1882.	Discovery of chrome iron ore in Cundagai, New South Wales, Australia. First attempt to mine chrome iron ore in New South Wales, in the Bowling Alley Point deposits, near Peel river.
1885.	First manufacture of chrome steel in the United States.
1886.	Mining of chrome iron ore in the townships of Wolfestown, Leeds, and Thetford, Province of Quebec.
1891.	First nickel chrome steel made in France.
1894.	Discovery of chrome iron ore near Black lake, in the township of Ireland, and especially in the township of Coleraine, Province of Quebec.
	Discovery of chromite at Bluff-Head, Port au Port bay, Newfoundland.
1898.	First chrome iron ore concentration on the shores of Black lake, by the Coleraine Mining Co.
1901.	First successful stamp mill erected by Mr. Whitney, on lot 9, range xiii, Coleraine, Quebec, belonging to the American Chrome Co., of Boston.

CHAPTER XI

DETERMINATION OF THE VALUE OF CHROMITE.

In the majority of cases the value of chrome iron ore depends principally upon the quantity of chromic oxide present, so that the determination of the latter may be considered sufficient; but if the chromic oxide is required for a specific purpose, it may be necessary to determine also the quantity of iron, silica, alumina, and magnesia.

Much difficulty was experienced by the chemists who first tried to analyse chrome iron ore: and this consisted chiefly in reducing the mineral into solution.

A convenient method for the valuation of chrome iron ore is the following: 0·5 gram of the finely powdered mineral is ignited with 10 grams of caustic soda, and 15 grams of magnesia, for one hour over a Bunsen burner, the powder being stirred with a platinum wire. After fusion the mass is treated with water, the filtrate acidified with hydrochloric acid, and the chromium determined volumetrically with ammonium ferrous sulphate.[1]

Another method which gives good practical results is the one described by T. H. Pratt[2] as follows:

"The mineral was fused several times with bisulphate of potash, then taken up with hydrochloric acid and tested for silica. Iron, aluminium and chromium were precipitated with ammonia, the precipitation being made at least three times. Magnesium, calcium and manganese were determined in the filtrates by the usual methods.

"The precipitate of the mixed oxides was dissolved in hydrochloric or nitric acid, and the excess of the acid evaporated. Sodium hydroxide was then added in excess, and chlorine was passed into the hot solution. The solution was acidified, and the iron and the aluminium were precipitated twice with ammonia and weighed as mixed oxides. These oxides, containing a trace of chromium, were fused with acid potassium sulphate digested with water, and acidified. One precipitation was made with ammonia to partially remove sulphates, and the precipitate was dissolved in hydrochloric acid and treated as before, the iron and aluminium being obtained free from chromium. The iron was determined volumetrically.

"To the filtrates containing the chromium, alcohol and hydrochloric acid were added, and the solution was digested for some time. The chromium was precipitated as hydroxide and weighed as Cr_2O_3. To ensure the purity of the precipitate, it was fused with 4 parts of sodium carbonate and one part of potassium nitrate; the fusion was taken up with water and tested for magnesia."

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[1] Berichte Deutscher Chemiker Gesellschaft, vol. x, p. 16

[2] Trans. Am. Inst. M. E., 1899, p. 31.

A volumetric estimation of oxide of chromium by means of arsenious acid in alkaline solution is given by C. Richard.[1]

This chemist utilizes the reducing action of arsenious acid upon chromic acid in alkaline solutions for the estimation of chromic acid, the method being especially adapted to the analysis of the lead chromates and other heavy metals. A solution of arsenious acid in 10 per cent solution of sodium hydrate is standardized by titration with iodine or potassium permanganate. A measured quantity of this standard solution is added to the alkaline solution containing the chromic acid to be determined, the mixture boiled for some time, and the excess of arsenious acid titrated back with iodine or potassium permanganate.

K. Seubert and A. Henke[2] have investigated the conditions under which the reaction between chromates and iodides in acid solutions may be employed for the estimation of oxide of chromium. if the compounds are present in the proportions indicated by the equation $K_2Cr_2O_7 + 6KCl + 14HCl \quad 8KCl + 2CrCl_3 + 7H_2O + 6I$, the iodine is liberated too slowly for analytical purposes. The authors found the proportions $K_2Cr_2O_7 + 18KI + 70H_2SO_4$ suitable, the reaction being complete in six minutes. In 160 cc. of solution there should be 0.5g.$K_2Cr_2O_7$, 0.5g.KI, and 1.8g.H_2SO_4.

When the reaction is complete the solution is diluted and titrated with standard sodium thiosulphate, using starch as an indicator.

A. G. McKenna, in the Proceedings of the Engineers Society of Western Pennsylvania, chemical section, 1863, describes the following method:

"One-half gram of the fine, ground sample, which has been dried at 100° C. for one hour, is weighed into a nickel crucible of about 20 cc. capacity, in which has been placed three or four grams of sodium peroxide. After thoroughly mixing the contents, the crucible is held over a Bunsen burner by means of a pair of suitably shaped tongs until fusion begins. The mass is kept in a liquid condition at a low red heat for about one minute, which is sufficient to ensure complete decomposition, if the ore is at all finely ground. After allowing the crucible to cool, it is placed in a 400 cc. beaker with a watch glass cover, and hot water is added until the crucible is covered.

"The beaker is placed on a hot plate for a few minutes until the fusion is completed; the crucible is then removed by means of a glass rod and the contents of the beaker are allowed to settle for a few minutes. When the insoluble matter has subsided it is collected on a 9 cm. filter paper, the filtrate being received in a 500 cc. flask. The residue on the paper, which contains all the iron, is ignited in a platinum crucible, fused with two or three grams of potassium bisulphate, dissolved in dilute sulphuric acid (1:10), reduced by filtration through amalgamated zinc, and titrated in the usual manner with standard permanganate. The result is calculated to ferrous oxide.

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[1] Chemiker Zeitung, 1900, p. 563.
[2] Zeitschrift fuer Angewandte Chemie, 1900, p. 1147.

"The filtrate in the 500 cc. flask, which contains all the chromium as sodium chromate in an alkaline solution, is boiled for about ten minutes in order to ensure the removal of all peroxide, which, if allowed to remain until the solution is acidified, would react on the chromate, reducing it to the sesquioxide.

"When the removal of the peroxide is complete, the solution is allowed to cool, and then acidified with a large excess of dilute sulphuric acid (1:4)

"The solution is transferred to a 1,000 cc. beaker, and diluted to about 800 cc. with cold water. To this solution 70 cc. of a ferrous sulphate solution, containing 10 grams of Fe in the ferrous condition to the litre, is added. This is sufficient to reduce the chromic acid corresponding to 0·3167 grams of chromic sesquioxide. The excess of ferrous sulphate which has been added is determined by back titration with standard permanganate solution, of which 1 cc. is equivalent to 1 cc. of the ferrous sulphate solution. Such a permanganate contains 5·643 grams $KMnO_4$ to the litre. The difference between the cubic centimetres of ferrous sulphate used and cubic centimetres of permanganate used, multiplied by 0·905, gives percentage of chromium sesquioxide in the ore."

Instead of the peroxide alone, it is suggested that a mixture of sodium hydroxide and sodium peroxide be used; because the hydroxide would tend to decrease the violence of the reaction, and thus there would be less chance of loss by spattering

Mr. H. G. Shaw[1] contributes the following description of the Clark process for the analysis of chrome iron ores, which is considered the most approved method:

"Powder about one gram of ore as finely as possible in an agate mortar, and mix with caustic soda and calcined magnesia, in the proportion of 10 parts caustic soda to 6 parts calcined magnesia. Heat the mixture in a deep platinum crucible, over a Bunsen flame, for about three-quarters of an hour, with the lid off, then with the lid on for a quarter of an hour. Oxidation takes place almost immediately, and is practically complete in less than an hour.

"The crucible and its contents are then placed in a porcelain basin containing water, the contents warmed and washed out as far as possible with water, and afterwards with dilute sulphuric acid, which must be free from nitric acid. An additional quantity of dilute sulphuric acid is then added to the contents of the basin, and more heat applied, when everything should dissolve except a few flakes of silica. To the clear yellow solution are added a weighed quantity of pure sulphate of iron and ammonia, of known strength, and more than sufficient for the reduction of the chromic acid. The unoxidized iron is then estimated by a standardized bichromate of potash solution, and the amount of sesquioxide of chromium in the ore calculated from the amount of iron oxidized, thus:—

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[1] Min. Inds., 1893, p. 164.

$$\begin{array}{ccc} \frac{6\,Fe}{336} & \frac{Cr_2O_3}{153} :: & \frac{Fe\ oxidized}{\times} \end{array}$$

"It frequently happens that a little of the chrome iron ore escapes decomposition. This must be filtered off after the chromic acid in solution has been estimated, and again fused with a mixture of soda and magnesia.

"To estimate the chromic acid by precipitation, add hydrochloric acid, then sodium sulphite to reduce the solution, then ammonia to precipitate the Cr_2O_3, and boil; then wash well by decantation several times, after which filter and continue washing, until the filtrate gives no precipitate, with chloride of barium ($BaCl_2$); then dry, ignite, and weigh the Cr_2O_3. Keep the precipitate, fuse it with soda and magnesia mixture, and continue estimating as per Clark's process."

Dr. Chas. Baskerville, of the University of North Carolina, and Dr. H. W. Foote, of the Sheffield Scientific School, Yale University, employed the following method on North Carolina chrome iron ore: –[1]

"The ore is first ground to an impalpable powder under water in an agate mortar. The powder is fused several times with bisulphate of potash, then taken up with hydrochloric acid. If a residue is left this should be dried and fused again with bisulphate of potash. The solution is tested for silica, and then the iron, aluminium, and chromium are precipitated with ammonia, the precipitation being made at least th[illegible]es, in order to throw down all these metals free from magnesia. The [illegible]te of these mixed oxides is dissolved in hydrochloric or nitric acid a[illegible] excess of the acid evaporated. Sodium hydroxide is then added in excess and chlorine passed into the hot solution. The solution is then acidified and the iron and aluminium precipitated twice with ammonia, leaving all but a trace of chromium in solution. These oxides, after having been dried and weighed (if iron and aluminium are to be determined), are fused with acid potassium sulphate, digested with water, acidified, and one precipitation made with ammonia to partially remove sulphates. On filtering, this precipitate is redissolved by hydrochloric acid and treated as before, the trace of chromium remaining in the solution. This solution is then added to that obtained before, and to the combined filtrates, containing chromium, alcohol and hydrochloric acid are added, and the solution is digested for some time. The chromium is precipitated by the addition of ammonia as hydroxide and weighed as Cr_2O_3. To ensure the purity of the precipitate, fuse with four parts of sodium carbonate to one part of potassium nitrate, take up the fusion with water, and test for magnesium.

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[1] Report. N. Carol. Geol. Survey, vol. i, 1895, p. 376.

"This method gives very satisfactory and accurate results, but one is required in the assay of ores that will give quick determinations of chromic oxide."

Volumetric Determination of Chromium: "A simple volumetric method for the determination of chromium in the presence of iron, taking advantage of the difference in reducibility of their sesquioxides, is presented by R. Glasmann.[1] The solution containing a mixture of ferric and chromic salts (but not more than 0·5 gram of chromic oxide on account of its colour), is treated in a flask, provided with a Bunsen's valve, with sulphurous acid, which reduces the ferric salt, leaving the chromic salt unaltered. The excess of sulphur dioxide is expelled by boiling, accompanied by the passage of a current of carbon dioxide, and the ferrous solution, after cooling, is titrated with permanganate. The oxidized solution is again reduced by heating with sulphuric acid and zinc according to Zimmermann's method, until it assumes an azure-blue colour. The ferrous and chromous salts are then again titrated with permanganate, the percentage of chromium being calculated from the difference between the two titrations."

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[1] Zeitschrift fur Analytische Chemie, 1904, xliii, 506, and Min. Ind., 1904, p. 72.

CHAPTER XII.

USES OF CHROMITE.

Chrome iron ore is used mainly in the manufacture of iron and steel alloys, which, when added to the bath of molten steel, imparts to it special properties. Attempts were made early in the sixties to prepare chromium, chrome steel, and chrome iron, and towards the end of the eighties sufficiently uniform products had been made in Brooklyn, in North Wales, Tarre Noire, Hoerde, and a number of other places. At Unieux, in France, rich, pure, chrome iron ore from Greece or the Urals was reduced in clay crucibles, yielding very good ferro-chromium containing 50 to 60 per cent chromium. Since that time a great number of innovations and improvements have been made in the production of chromium alloys, especially of ferro-chrome, and the adoption of the latter by the Krupp works in Essen, Germany, for the production of armour plate for protective purposes for war vessels, has attracted general attention.

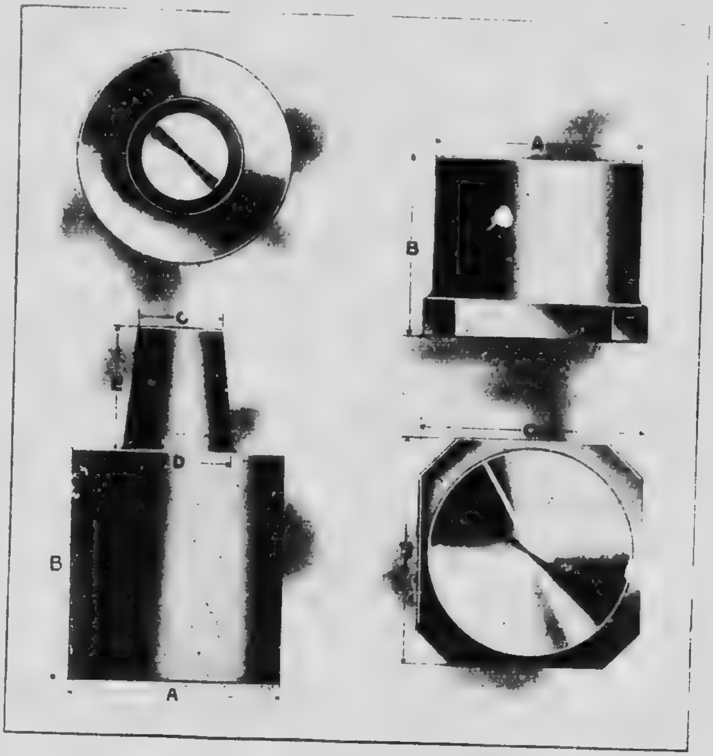
Chrome Steel.- The peculiar properties of chrome steel may be summed up as follows:

Chrome steel is hard to break, and shows a fibrous fracture in hardening at suitable temperature; the texture becomes finer graded in proportion to the percentage of chromium in carbon. Steel with 1 to 1·5 per cent carbon, and 2·5 to 4 per cent chromium is so hard that it cannot be worked with the ordinary hardened tools, but if such steel is hardened in water it gets brittle. Chrome steel does not peel off in hardening in water; the layer of oxide sticks on. By heating too long or too violently, the steel loses its quality. Chrome steel solidifies much quicker than ordinary steel, and this is most noticed at a percentage of 5. For this reason chrome steel production requires very high temperature. The castings shrink much more violently in cooling, resulting in many inconveniences. These are the harder to avoid in proportion as the castings are larger. Chrome steel shows very fine grain, and extraordinary thickness, is more sensitive to sudden and to gradual strain, and is, therefore, better fitted for lathe tools and drills, and for chisels. In this particular it excels the best ordinary cast steel. Chrome steel, though hard, bends well cold if the operation is slow enough. It can be welded to iron and rolled out, and finds use in sheet metal or rod metal, especially as material for burglar proof safes, wire, magnet steel, cutlery, bridge steel, tires, axles, springs, stamp mill shoes, crusher jaws, and knuckles for car couplings.

Chrome steel is extremely hard, tough, and dense. It is possessed of great tensile strength and is superior to any metal known for the wearing parts of mills used for crushing and pulverizing gold, silver, and other ores. This steel is especially adapted to severe service and resistance to abrasion;

and for the wearing parts of stamp mills, such as battery shoes, and dies, cams, tappets and bosses, chrome steel has proven, by reason of its durability, the most economical and satisfactory material to be obtained.

In the Chrome Steel Works at Chrome, N.J., the shoes and dies for stamp mills are compressed hot in an hydraulic forging press. This process of manufacture, it is claimed, removes from the middle all internal shrinkages, porosity, etc., and ensures a steel of absolutely equal density throughout the mass. Chrome steel forged in this manner will wear evenly to the end, and is reported to give longer service than any make of cast or hammered material. By this method shoes and dies can be produced which do not chip or split or break o[illegible] the shank; which frequently occurs with ordinary hammer forged steel and with cast shoes and dies. Dies of this manufacture are especially adapted for gold mills where the dies wear with an excessive percentage of waste, and where the conditions in milling are such that economy is demonstrated in renewing dies when about half worn out, and where it is desirable to maintain a high discharge from the mortars



Shoe. Plain square, clip boss die.

FIG. 12—Chrome Steel Shoes and Dies.

Chrome steel resembles in some respects the higher grades of tool steel; but in addition is possessed of properties combined in no other known steel.

It will harden drill-proof against the finest tools when heated to a moderate heat and plunged into water.

These properties of chrome steel are invaluable to the proper manufacture of burglar or tool proof material. It is shown conclusively that on account of the frequent escapes from jails constructed of iron or soft steel, cells if built of material that is capable of being drilled or sawed afford insufficient security against outbreaks. Chrome steel jail bars and plates are proof against all cutting tools. Fig. 13 represents a round bar having a tough centre core of fibrous iron, entirely surrounded and protected by a circular layer of chrome steel, which in turn is surrounded by an outer covering of iron. This bar, as

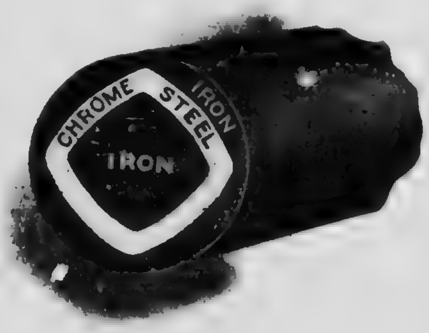


Fig. 13—Burglar Proof Round Chrome Steel Bar, as manufactured by the Chrome Steel Works at Chrome, N.J., U.S.A.

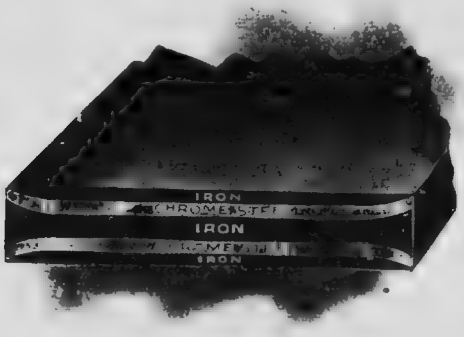


Fig. 14—Burglar Proof Flat Chrome Steel Bar, as manufactured by the Chrome Steel Works at Chrome, N.J., U.S.A.

manufactured by the Chrome Steel Works at Chrome, N.J., is used in the construction of cells, corridors, window guards, and gratings. Fig. 14 represents a flat bar having alternate layers of iron and chrome steel. This bar is used for lattice work, and diamond gratings for jail cells, etc.

After the materials are hardened and put together they cannot be cut by the finest tools, saws, drills, or chisels, as the steel is much harder than such tools can be made of. They cannot be broken, as the steel is thoroughly protected against abrasion from blows, and is entirely covered by and welded to layers of the toughest iron.

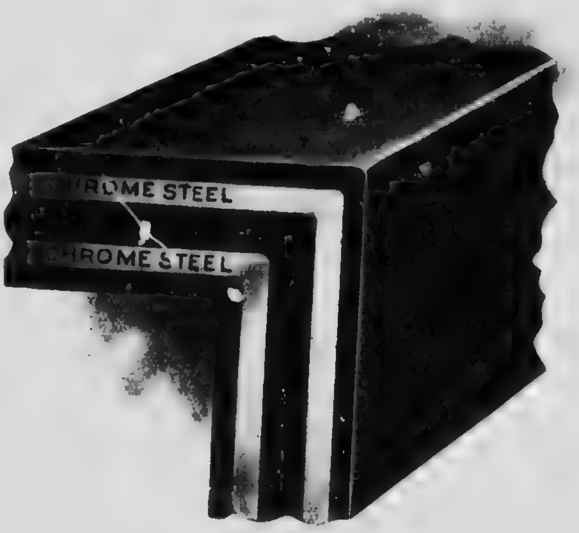


Fig. 15.—Burglar Proof Armour Plate for Safes.

L. Guillet,[1] in a lecture on chrome steel, gives some interesting information regarding the properties of chrome steel. Up to the present time chrome steel has been manufactured with only a small content of chromium from 1 to 3 per cent. Armour plates contain as a rule 2 per cent chromium and a certain quantity of nickel; but in very limited quantities, and only for special purposes, some brands were manufactured containing 5, in rarer cases 7 per cent chromium. Recently, however, steel containing as high as 15 and 20 per cent chromium, and about 3·5 per cent carbon, has been produced in the electric furnace at Kunrich, Sheffield (Eng.). The most remarkable quality of this class of steel is its brittleness when freshly manufactured and its great ductility after it has been tempered.

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[1] Société d'encouragement pour l'industrie nationale, meeting of Dec. 6, 1907

OTHER CHROMIUM ALLOYS.

There are quite a number of alloys of chromium with iron and nickel, and nickel chromium steels are largely used in the manufacture of armour plates. The properties of nickel chromium steel that make it especially adapted for use in the manufacture of armour plates are its hardness, great tensile strength combined with great ductility, and a very high limit of elasticity, and the fact that when perforated by a projectile it does not crack.

Alloys of chromium made by the alumino-thermit process at Essen, Ruhr, Germany, are a chrome-manganese alloy free from carbon, containing 30 per cent of chromium and 70 per cent of manganese; a chromium molybdenum alloy free from carbon, containing 50 per cent of chromium and 50 per cent of molybdenum; and a chrome copper alloy free from carbon, containing about 10 per cent of chromium.

Chromite as Hearth Lining for Furnaces.—Chromite is being used now in the manufacture of bricks for basic open hearth-furnaces, but their general introduction is somewhat impeded by the high cost. The binding material may be bauxite, lime, or it may be simply the impurities accompanying the chromite. If lime or bauxite are employed, about 2 per cent of CaO and 25 per cent clay or bauxite are used. A United States patent has been issued for the use of gypsum and aluminium sulphate in the proportion of 2 per cent of the former and 1 per cent of the latter. This is said to possess an advantage in that, it gives plasticity to the mass, and also renders it slightly more fusible: as when heated the gypsum and aluminium sulphate are converted into CaO and Al_2O_3, with a consequent reduction in percentage to 0·85 and 0·15 respectively.

The Harbison & Walker Company, of Pittsburgh, Penn., make a chromite brick which stands at least 400 heats. The price of these chromite bricks is considerably higher than that of silica bricks, but it is claimed that they last much longer, and for this reason repairs in the furnace are reduced to a minimum. Chromite bricks are also used for quick repairs in furnaces while they run at full blast, because these bricks are not affected by either sudden heating or sudden cooling.

Mr. William Glenn, of Baltimore, describes in a paper read before the American Institute of Mining Engineers, 1901, the use of chromite as a hearth lining for furnaces smelting copper ore. He describes fully the results of the construction of a chrome iron ore bottom for a water jacketed cupola copper furnace built at the Elizabeth mine at Stratford, Vt. The work on this furnace was done under the management of Mr. James W. Tyson, Jr., of Baltimore. The details of construction are given by Mr. Glenn, as follows:

"To contain the chrome iron ore, and form with it the furnace bottom, he constructed a cast-iron basin with surrounding flange, the outer edges of which coincided with the exterior walls of the water jacket. The bottom of the basin is a united arch of 36″ chord and 12″ versed sine.

and 1″ in thickness, except the flanges, which are 1¼″ thick. It is in two sections, each of which is 5′-7″ long. Each section is reinforced by three ribs, 1″ in thickness and depth, by means of two of which the sections were bolted together, with an asbestos gasket in the joint. The two outer ends of the basin were closed by segments which were cased with the sections. The basin was supported by ten jackscrews placed under its flanges, and was thus held up securely against the bottom of the water jackets, leaving free for inspection the entire underside of the basin. The chrome iron ore was filled into the basin, just filling the basin, and reaching no higher than the bottoms of the four water jackets which form the four walls of the cupola. The ore used was of all sizes from 10″ cubes and downward through all dimensions even to dust.

"The lumps of ore were fitted in as well as possible; the interstices were then filled in with smaller lumps, which were hammered in; finally, the cracks were filled with ground ore, thus making the bottom of the furnace consist of well-packed ore. A course of fire bricks, standing on end, was laid over the whole of the chrome iron ore hearth. It has not been determined what depth of firebrick should be employed, or whether any covering at all is needed. This chromite cupola bottom has given satisfaction for over a year, where a corresponding firebrick bottom would not have lasted more than a week.

"A blister-copper reverberatory furnace was erected at the same mine in Stratford, Vt., and chromite was used in the hearth and adjacent walls, the bridge wall being entirely constructed of chrome iron ore. The slag line of the hearth was built around with chrome iron ore, and neither this nor the bridge wall has shown any noticeable attack upon them.

"Our experience leads us to believe that the bridge wall of a blister-furnace should be lined with blocks of chrome iron ore, compacted as far as possible, and that the slag line of the furnace hearth should be formed of blocks of chrome iron ore about 10″ in height. We would build the larger blocks into the walls, as best we could, and then wedge the smaller ones in among them. The work would appear rude and unskilful when looked upon after completion. Blocks of chrome iron ore are rough in outline; they do not readily lend themselves to wall building. There is no mortar wherewith to form an inviting exterior to the work, and there is no other deceitful adjunct present."

The reasons given for the application of chromite for furnace linings are as follows:—

It is not affected at all by sudden heating or cooling; it is infusible; it does not become friable when heated and cooled, and it is not attacked by the products formed in the fusion of the ore. Its resistance to all kinds of acids and fused slags is well known. All these qualities go to prove that as a mineral it will be more universally used in future, and there is no doubt that smelters will find it to their advantage to have their furnaces lined with chromite.

Chromium Salts. The principal use of chrome iron ores is in the manufacture of salts, chromate, and bichromate or *di*chromate of potash, which are especially employed in dyeing; and in the manufacture of colouring material of pigments. The invention relating to the manufacture of these salts as pigments was made in the early part of the nineteenth century, and although the employment of the latter was not well recognized and established at that time, their use in the colouring trade became more general as soon as large deposits of chromite were discovered in Asia Minor and near Caledonia. It may be said that these salts are practically indispensable in the manufacture of textiles and artistic colours.

Potassium dichromate is used extensively in the preparation of chrome yellow and chrome orange, which find a ready use as pigments in calico printing; as chrome black in dyeing; for the oxidation of caoutchouc and Berlin blue; the discharge of indigo blue; the bleaching of palm oil and other substances; the preparation of mixtures for the heads of lucifer matches; and the preparation of marcerus chromate and chromate oxide which are used as green pigments in the ceramic arts.

Chromate of potassium is further used in the manufacture of aniline colours and chlorine gas, and for many other purposes in the chemical industry, where it is an exceedingly important re-agent.

The potassium and sodium bichromates form the base from which numerous chromium compounds are obtained. Chromic acid, CrO_4, is obtained by decomposing potassium dichromate with sulphuric acid. It is used instead of nitric acid in galvanic batteries. Neutral lead chromate, or chrome yellow, $PbCrO_4$, is prepared by precipitation of a solution of potassium chromate with a solution of lead acetate, or by the use of lead sulphate or chloride. This salt, which has a beautiful sulphur-yellow colour, is a valuable pigment. The basic lead chromate, known also as chrome red or Austrian cinnabar, which is represented by the formula $PbCrO_4 + PbH_2O_2$, is obtained from the yellow or neutral chromate of lead, by boiling with a solution of potassium hydrate, or by fusion with potassium nitrate, the effect being that half the chromic acid is withdrawn from the neutral chromate. The pigment known as chrome orange is a mixture in various proportions of the basic and neutral chromate of lead. Chromic oxide, or chrome green, Cr_2O_3, is especially valuable as a pigment, being indelible, wherefore it is employed in printing bank notes.

Chrome tanned leather.—W. Eitner[1] points out that chrome-tanned leather is better adapted than any other tanned material to certain technical purposes, such as the manufacture of hose to be used with hot liquids, high speed belts, etc., by reason of its insolubility and its superior heat resisting properties. The author ascribes the high power of resisting external influences which this material possesses, to the fact that, in chrome tanning a more thorough penetration of the tanning substance into the hide is obtained than is possible with vegetable tanning.

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[1] Min. Ind., 1900, p. 88.

Chrome solutions for tanning leather.[1] Chromium compounds for tanning leather were used as early as 1856, but early experiments were not successful, as the tannage was not permanent. The discovery of sodium thiosulphate to make the tanning permanent was due to W. Zahn, who patented his process in the United States on June 28, 1888. The process consists in dipping the skin in a solution of a chromium salt, acidified with HCl, and then into a solution of $Na_2S_2O_3$ or $NaHSO_3$ acidified with HCl or H_2SO_4. For tanning 100 lbs. of skin, 4 to 5 lbs. $K_2Cr_2O_7$, 2·5 to 4·5 lbs. HCl, 8 to 10 lbs. $Na_2S_2O_3$, and 0 to 1·5 lbs. H_2SO_4 are required. A number of electrical processes for tanning skins with chromium salts have been patented in the United States.

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[1] Ibid, 1902, p. 124.

CHAPTER XIII

TECHNOLOGY OF CHROMIUM AND ITS COMPOUNDS.

The writer did not think this treatise complete without giving a synopsis of all that is generally known regarding the manufacture of chromium, chromium alloys, and salts, and for this purpose abstracts of articles are given which have been published in scientific and technical journals, supplemented by private information received from various manufacturers.

Ferro-chromium. In the manufacture of ferro-chromium alloy, it is necessary that the chromite, which should be a high grade article, is low in silica; for the reason that, on account of its refractory character, the latter can be reduced only by the employment of electric heat. Ferro-chrome alloys may be manufactured in the electric furnace, the crucible furnace, or the blast furnace; but at the present time they are made almost exclusively in the electric furnace. Formerly, before the general application of electricity for power purposes, the principal method of making ferro-chrome was in blast furnaces. Only a low grade ferro-chrome alloy could be obtained by this process, the chromium content being from 30 to 40 per cent. With the introduction of the electric furnace, however, the chromium content has been increased to 60 per cent and upward, and at the present time the alloys that seem to be in the greatest demand are those containing 60 per cent or more of chromium. The main objection to the use of crucible furnaces is that, only small quantities of the ferro-chrome alloy can be prepared at one time, but the chromium content is very high. Where formerly these ferro alloys were apt to contain a rather high percentage of carbon, the processes have now been so improved and regulated that ferro-chrome alloys can be made which contain but a fraction of one per cent of carbon, and the product can now be made approximately uniform.

A ferro-chromium alloy has been made by the Rossi[1] process which has the following composition:

Chromium	68·24%
Iron	26·92%
Silicon	1·85%
Carbon	1·00%
Aluminium	0·50%

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[1] U.S. Min. Res., 1904, p. 323

The ores from which this ferro-chrome was made have the following analysis:

ANALYSIS OF CHROME IRON ORE.

Constituent	Per cent	Constituent	Per cent
Cr_2O_3	50.29	CaO	1.15
FeO	16.01	S	0.01
Al_2O_3	10.72	Moisture	1.46
SiO_2	4.62		
MgO	16.61	Total	100.87

The principal firm in Canada which manufactures ferro-chrome is the Electric Reduction Company, at Buckingham, Que. Other foreign firms are the following:

Wilson Aluminium Company, at Kanawha Falls, W. Va., and Holcomb Rock, Va., U.S.A.; Chrome Steel Works, Brooklyn, N.Y., U.S.A.; the Hecla Works, Sheffield, England; George G. Blackwell Sons & Co., Limited, Liverpool, England; Hugo Krupp, Hanover, Germany. In France there are a number of plants manufacturing ferro-chrome as follows:

Société Electrométallurgique Française, at La Praz; Société La Néo-Métallurgie, at Giffre; Société Anonyme Electrométallurgique, at Albertville; Keller, Leleux & Cie., at Livet; Société Electrométallurgique de Saint-Béron, at Saint-Béron; Ch. Betrolus, at Bellegarde; Rochette Frères, at Epierre.

There are quite a number of forms of electric furnaces in use in the manufacture of the ferro-chrome alloys.[1] The Wilson Aluminium Company uses a furnace in which the crucible constitutes one of the electrodes. The furnaces are of partly circular, partly square, and partly rectangular cross section; their outside dimensions vary from 120" wide, × 80" long × 60" high in the largest; to 60" square, × 50" high in the smaller ones. The furnaces consist of iron boxes, with very thick linings of pieces of anode carbon with tar binder, and they are provided with tapping holes. In a few of the furnaces the lining constitutes one electrode, while the other is formed by a bar of carbon which hangs vertically in the furnace; others have two parallel electrodes, which hang vertically in the crucible, and are movable in this latter type. The crucible is not connected into the electric circuit. These hanging electrodes consist of carbon bars 60" in length, with a cross section of 4" × 4", one electrode being formed by two bars side by side; and they are fastened into the iron heads, which are kept cool by means of water. In operating these furnaces the carbon lining is gradually replaced by material of the mill, until finally the crucible is practically lined with the same material as that which is melted. An alternating current of 110 volts pressure, and of 22,000 amperes, is divided over seven different furnaces. The energy consumed in the production of these ferro-chrome alloys is about 10·6 h.p. hours per kilogram of the product obtained.

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[1] U.S. Min. Res., 1904, p. 324.

The Wilson Aluminium Company is making ferro-chrome principally from Turkish and new Caledonia ores, with smaller quantities from Canadian and Cuban ores. In the following table a series of analyses are given of some of the ferro-chrome alloys on the market :—

ANALYSES OF FERRO-CHROMIUM ALLOYS.[1]

Constituent.	1.	2.	3.	4.	5.	6.	7.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Chromium	67·000	71·980	66·00	64·050	63·586	69·600	60·00
Iron	24·380	22·610	28·60	25·450	35·596	28·452	35·00
Carbon	8·050	4·789	4·90	8·550	0·650	1·560	1·00
Silicon	0·490	0·550	0·50	1·880	0·140	0·350	......
Sulphur	0·007	0·061	......	0·046	0·028	0·038	......
Phosphorus	0·005	0·008	......	0·025	Trace	Trace	......
Total	99·932	99·998	100·00	100·001	100·000	100·000	96·00

(1) Crystalline ferro-chromium alloy manufactured by the Wilson Aluminium Co.

(2) Solid ferro-chromium alloy manufactured by the Wilson Aluminium Company.

(3) Ferro-chrome alloy obtained from Canadian ore and manufactured by the Wilson Aluminium Company.

(4) Ferro-chrome alloy manufactured by George G. Blackwell Sons and Co., Ltd.

(5) Ferro-chrome alloy, refined No. 1, manufactured by George G. Blackwell Sons and Company, Limited.

(6) Ferro-chrome alloy refined No. 2, manufactured by George Blackwell Sons and Company, Limited.

(7) Approximate composition of ferro-chrome alloy manutactured by the Société la Néo Métallurgie. Carbon content ranges from 0.4 to 1 per cent.

Société la Neo Métallurgie manufactures in the ferro-chrome nickel alloy of the following percentage composition:

16 to 38% of iron.
24 to 57% of chromium.
5 to 60% of nickel.

0·30 to 0·80% of carbon with a very small amount of silicon and traces of sulphur and phosphates. This Company also manufactures a ferro-chrome silicon alloy which contains 50 per cent of chromium, 38 per cent of iron, 8 to 10 per cent of silicon, and 2 per cent of carbon.

Since the year 1902, efforts have been made to use metallic chromium instead of ferro-chrome in the manufacture of chrome steel.

When chromium metal was first introduced on the market it was said that the use of ferro-chrome for this purpose was more advantageous;

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[1] Ibid, p. 325.

because the metallic chromium when first manufactured contained carbon, which made it more difficult to fuse. However, metallic chromium free from carbon has been produced by the alumino-thermit process, and while there is a difference in fusibility between the ferro-chrome and the pure chromium, it is not sufficiently graded to be an impediment in the use of the metal chromium for the manufacture of chrome steel. There is one thing which would speak in favour of the use of metallic chromium, and that is its uniform composition. Metallic chromium free from carbon, containing 97 to 98 per cent chromium, is now made according to the Goldschmidt process, in Essen-Ruhr, Germany. The metal contains as impurities some traces of iron and silicon; it is brittle, of very bright lustre, and with a melting point higher than that of platinum.

Prof. Roland Calberta[1] recently stated before the New York section of the Society of Chemical Industry that a series of experiments had been carried out with a view to producing ferro-chrome, in an electric furnace, from pure chromic oxide and iron or magnetite. The aim was to reduce the percentage of carbon to a minimum, and to increase the chromium to a maximum.

The best results were obtained when using a lime-fluorspar slag, to which chromite was added, the melting being continued for half an hour; longer periods increased the refining effect, but decreased the yields, especially that of chromium. The losses of chromium in all the experiments were very heavy. It was concluded that it is impossible, under the conditions obtainable, to entirely eliminate the carbon.

Steel-making with Chromiferous Iron Ores. H. H. Campbell, of Steelton, Pa.,[2] proposes to use iron ore containing from 1 to 5 per cent chromium for the production of steel low in chromium. He has succeeded in producing a steel containing only 0·08 per cent Cr. It is well known, if steel has a content of chromium in excess of a certain small proportion, it is practically unfit for use in engineering work; and also that it has not been practicable to make use of iron rich in chromium as a starting metal for the manufacture of steel on a profitable basis, especially on a large scale, because of inability to effect the economical removal of the chromium. Mr. Campbell's method is first to treat the chromium-iron in a basic Bessemer converter, producing a basic slag, and then to oxidize the chromium by prolonging the blow beyond the usual period, which causes the chromium to enter the slag. The charge is then drawn from the converter into a ladle (having a device for drawing the metal from beneath the slag and then stopping or controlling the flow of slag). The subsequent treatment depends on the final use for which the steel is intended. For low-carbon steel, if the de-chromized metal does not contain much oxygen, it is incorporated with ferro-manganese to obtain the usual reaction; if the de-chromized metal contains considerable oxygen, it is charged into a second converter having a siliceous lining, with an addition of unblown molten iron (free from chromium and having a higher carbon content), and is finally re-carburized.

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[1] Mining World, July 11, 1908, p. 54.

[2] United States patent, No. 795,193, and Min. Ind., 1905, p. 77.

Obtaining Metallic Chromium.—C. Goldschmidt describes[1] a new and exceedingly simple way of reducing metallic chromium from solutions of its salts. "Metallic chromium can be separated from solutions of its salts by contact with metallic zinc or its alloys. Thus, if a solution of chromium nitrate be allowed to stand in the cold in a zinc vessel, chromium is deposited partly in the amorphous and partly in the crystalline form, in the course of a day. The chromium hydroxide simultaneously deposited can be removed by treatment with alkali in excess. The best results are obtained with crystalline chromium nitrate, other chromium salts not b[illegible] so suitable for the purpose.

Potassium and Sodium Bichromates.[2]—"Chromate of potassium ([illegible].)—the yellow, neutral salt—is prepared by heating chrome iron ore, pre[illegible]ly pulverized and elutriated, with potassium carbonate and nitrate on the hearth of a reverberatory furnace. The oxygen of the saltpetre superoxidizes the ferrous oxide and chromium sesquioxide, the latter being converted to chromic acid, which combines with the potash to form potassium chromate. The thoroughly sintered (not molten) mass is withdrawn from the furnace, cooled, crushed, and lixiviated with boiling water to extract the chromate. Wood-vinegar is added to the solution to precipitate any alumina and silica that may have been dissolved, after which the clear liquor is evaporated to proper strength for the crystallization of the potassium chromate. The neutral salt is converted to the acid salt, or dichromate ($K_2Cr_2O_7$), by adding sulphuric or nitric acid to the solution. It is preferable to use nitric acid on account of the formation of potassium nitrate, which may be used in the decomposition of a fresh quantity of ore.

"In Vauquelin's process the chrome iron ore is decomposed by heating with chalk, and leaching with hot water slightly acidified with sulphuric acid, which converts the calcium chromate formed in the furnace to calcium bichromate. The ferrous sulphate taken into the solution is precipitated by chalk. The calcium bichromate is converted to the corresponding potassium salt by the addition of potassium carbonate, which throws down the calcium as carbonate, while the potash takes its place in combination with the chromic acid.

"The Tighlman process consists in heating the ore in a reverberatory furnace with lime and potassium sulphate. In Swindell's process the chrome iron ore is ignited at the highest possible heat with an equal amount of either sodium or potassium chloride, exposing the mixture at the same time to a current of super-heated steam, the formation of sodium or potassium resulting.

"The most important improvement in the manufacture of potassium chromate, according to Wagner's Chemical Technology (Crookes and Fischer), 1892, p. 469, has been the substitution of potash for saltpetre, and the use of a furnace so constructed as to admit of the proper access of air to the strongly heated mass, the oxygen of the air being made to oxidize the chromic oxide to chromic acid. Another improvement is that, in using lime instead of alkali, the oxidation of the chromic oxide is greatly accelerated, because the heated charge does not become pasty, but remains pulverulent, and admits a readier access of air, as well as preventing the sinking of a portion of the chrome iron ore to the bottom of the hearth, where it is withdrawn from the chemical action of the furnace.

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[1] Chemiker-Zeitung, 1905, xxix, 56, and Min. Ind., 1904, p. 71.
[2] Min. Ind., 1893, p. 159.

"Sodium carbonate has been partially substituted for potassium carbonate in the decomposition of chrome iron ore on account of its lower cost, the resulting product being, of course, bichromate of soda. There were difficulties in this innovation which prevented its introduction for a long time, but about 1880 a successful process was devised by German chemists, since which time the sodium bichromate industry has become very important, bringing down the price of potassium bichromate rapidly. In 1882 the price of potassium bichromate was 15¼ cents per lb., in 1883 it fell to 12 cents, and in 1884 to 10½ cents. At the present time the price is still 10½ cents. The manufacture of sodium bichromate was undertaken at the Baltimore Chrome Works in 1884."

The process of sodium bichromate manufacture in Europe has recently been described by C. Häussermann, in an article from which the following is produced:[1]—

"The raw material employed in this manufacture is chrome iron ore, which is chiefly obtained from Turkey, or Asia-Minor. The analysis of a sample of such an ore gave the following figures:– Cr_2O_3, 51·20%; Al_2O_3, 12·80%; Fe_2O_3, 1·45%; FeO, 13·32%; MgO, 12·55%; CaO, 3·15%; SiO_2, 4·95%; CO_2, 0·20%; loss, 0·38%.

"The ore must be ground to an almost impalpable powder, and for this purpose roller mills have been found to give the best results. The powdered ore is then mixed with lime and sodium carbonate, which must also be very finely ground. The mixture is then submitted to an oxidizing roasting. The reaction taking place is expressed by the formula:

$$2FeCr_2O_4 + 4Na_2CO_3 + 7O = Fe_2O_3 + 4Na_2CrO_4 + 4CO_2.$$

"In practical working the addition of lime is indispensable, making the mass porous and preventing the sodium carbonate from fusing, which would lead to incomplete oxidation. The proportions in which the above ingredients are to be used are, in England, according to Atcherley, 4·5 parts of ore, 7 parts of burnt lime, and 2·25 parts of alkaline carbonate. In Russia, according to Walberg, there are used 6 parts of ore, 3 parts of chalk, and 3 parts of soda-ash. Generally, mixtures containing more lime than soda give the best results as regards the percentage of chromium rendered soluble. Even less sodium carbonate, as required according to the above equation, may be employed, in which case a corresponding quantity of chromate of lime is formed. The roasting operation is carried out in reverberatory furnaces, so constructed as to heat the air to a temperature of about 400° C. before it enters the furnace proper.

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[1] Dingler's Polytechnisches Journal, 288, p. 93, iii.

"A furnace consuming four tons of coal in twenty-four hours will roast during the same period two tons of ore. The working space of the furnace is divided into three beds, each succeeding bed being slightly higher than the one nearest to the firebox. One-third of the daily charge is first introduced into the furnace through a hopper over the third and highest bed of the furnace; after eight hours it is raked down onto the second bed, while the third or top bed receives a fresh charge. After another eight hours the first two charges are worked down to the first and second beds respectively of the furnace, the top bed again receiving a fresh charge. The temperature of the first bed, close to the firebridge, should approach that of melting gold, the last bed that of melting aluminium. The yield of roasted material is about 5 per cent less than the weight of the unroasted charge. Scarcely more than 1 per cent of the ore escapes oxidation into chromic acid. The roasted mixture, together with about twice its weight of water, and sufficient soda-ash to leave an excess of 5 per cent over and above the quantity required for the formation of the normal chromate, is then transferred into iron cylinders provided with agitators and heated to from 120° to 130° C., for about two hours. The solution is eventually separated from the insoluble residue by filter-pressing. The composition of the residue is exhibited in the following analysis: Na_2O, 0·2%, CaO, 46·5%; MgO, 12·2%; Fe_2O_3, 7·5%; Al_2O_3, 5·4%; Cr_2O_3, 1·0%; soluble in HCl;—CrO_3, 1·8%; SiO_2, 1·4%; CO_2, 5·2%; H_2O, 16·0%; insoluble, 1·2%.

"The solutions obtained from the filter-presses are concentrated until they attain a sp. gr. of 1·5. They receive then the addition of such a quantity of sulphuric acid (containing 80% H_2SO_4) as will suffice to neutralize the excess of alkali present and convert the whole of the monochromate into bichromate. The largest quantity of the sulphate thus formed at once precipitates in its anhydrous form, the bichromate remaining in solution. This operation is carried out in lead-lined iron pans, which are provided with a steam jacket. The solution of the bichromate is separated from the precipitated sulphate by first siphoning off the clear solution of bichromate, and hydro-extracting the residue. The bichromate solution is further concentrated in iron pans. Considerable quantities of sulphate crystallize aut, but as soon as a sp. gr. of 1·7 is reached the hot solution is filtered and allowed to stand and crystallize. If the crystallization proceeds undisturbed, large crystals of $Na_2Cr_2O_7+2H_2O$ are obtained; but if during crystallization the solution be agitated, the salt crystallizes in the form of small orange needles. The sp. gr. of the larger crystals is 2·6.

"Bichromate of soda is very deliquescent, and imparts to absolute alcohol a yellow colour; the corresponding potassium salt does not give this reaction. The yield amounts to about 90 per cent of that calculated. To convert the sodium salt into the potassium salt, solutions are used, containing respectively 1,500 grams of $Na_2Cr_2O_7+2H_2O$ and 300 grams of KCl per litre, the latter solution being added to the former. The bulk of the bichromate of potash is at once precipitated and recrystallized, large crystals being obtained from solutions containing 570 grams $K_2Cr_2O_7$ in one litre.

The mother liquors are used for the crystallization of fresh quantities of the crude salt. The mother and wash liquors obtained in this manufacture, which are too much contaminated with foreign salts, are treated with reducing agents, and the chromium oxide precipitated, and subsequently filter-pressed. The chromic oxide cakes thus resulting are mixed with lime in the proportion of 1 Cr_2O_3 to 1·5 CaO. The mixture is dried and heated to redness, until the mass possesses a homogeneous yellow appearance and contains about 36% of CrO_3. The roasted mass is then extracted with carbonate of soda. In the same manner the chromium may be recovered from the waste liquors of alizarin works. The hurtful effects of chromates upon the health of the workpeople can be considerably minimized by adopting the necessary precautions. No workmen ought to be allowed to work while suffering from abrasions or wounds on exposed parts of the body; as upon these, on contamination with chromates, ulcerated sores, healing but slowly, are formed. The hands ought to be rubbed with vaseline, and no food or drink allowed in the work sheds.

"The conversion of chromite of soda into chromate can be effected by means of the electric current. On submitting a solution of chromic oxide in caustic soda to electrolysis, using platinum as anode, and iron as cathode, the following reaction takes place:—

$$Na_2Cr_2O_4 + 2NaOH + 3O = 2Na_2CrO_4 + H_2O.$$

"A current of two amperes was employed, and it was found that one hour ampere converted 0·563 gram of the chromite into chromate. One hour ampere yielding theoretically 0·298 gram of oxygen, which would oxidize 1·336 gram of $Na_2Cr_2O_4$, it follows that the useful effect represented by $\frac{100 \times 0{\cdot}563}{1{\cdot}336} = 42\%$ is attained."

Chrome Tannage.—A process for the manufacture of chrome tannage is described by Thorp in Outlines of Industrial Chemistry, 1905, p. 541. "Chrome tannage, or tanning with chromium salts, has been chiefly developed in the United States, and is now in general use there. The principle of the process consists in precipitating an insoluble chromium hydroxide or oxide on the fibres of a skin which has been impregnated with a soluble chromium salt, usually potassium bichromate; basic chromium chloride, chromium chromate, and chrome alum are also used. The skins, having been limed, unhaired, fleshed, bated, drenched, and scudded, are worked in a solution of potassium bichromate, to which some common salt has been added, together with one-fourth to three-fourths of the theoretical amount of hydrochloric or sulphuric acid necessary to liberate all the chromic acid (CrO_3). After several hours, when the skin shows a uniform yellow colour when cut through the thickest part, it is removed, the excess of water pressed or drained away, and the skin worked in a bath of sodium bisulphite ($NaHSO_3$) or thiosulphate, to which has been added some mineral acid to liberate the sulphur dioxide:—

(1). $K_2Cr_2O_7 + 2\ HCL \quad 2\ KCL + H_2O + 2\ CrO_3$

(2). $Na_2S_2O_3 + 2\ HCL \quad 2\ NaCL + H_2O + S + SO_2$

(3). $2CrO_3 + 3\ SO_2 = 3\ H_2O + 3H_2SO_4 + Cr_2O_3$

"The chromic acid is absorbed by the fibre, and is later reduced *in situ* by the sulphurous acid. It is necessary to use a strong solution of the reducing agent, so that the reduction may be fully accomplished before the chromic acid has time to bleed from the skin. The strength of solutions recommended vary somewhat in the various processes, but are usually made from 10 to 30 grams per litre for the bichromate, and 30 to 50 grams for sodium thiosulphate. Calculated on the weight of the skin, from 4 to 9 per cent of bichromate, and about 15 per cent thiosulphate, are usually employed. The amount of chromic acid fixed on the fibre is about 4 to 6 per cent, calculated as bichromate, $K_2Cr_2O_7$.

"Chrome leather is tough and resists moisture very thoroughly. On this latter account, skins which are to be dyed should be introduced into the dye at once after reducing and washing, for if allowed to dry, the dyeing is incomplete. The leather may be heated to 80°C. or more without injury, and hence can be dyed with some of the alizarin colours. It is a very rapid process, the time of steeping in the chrome bath being only a few hours, and even less in the reducing bath. It is a very light tannage, and on thick skins has considerable tendency to contract the fibre, and so is not used for sole or upper leathers. It is chiefly employed for glazed kid, calf kid, and glove leathers. The tanned or coloured skins are oiled and stuffed before drying."

APPENDIX I

NOTES ON THE METALLURGY OF CHROMIUM.

By W. BORCHERS.[1]

The metal chromium is not found native, but in combination with oxygen and other metals it occurs as crocoite, a lead chromate of the formula $PbCrO_4$, and chromite, $FeCr_2O_4$, a salt of metachromous acid. The latter mineral, in the form of irregular and crystalline masses varying from brown to black in colour, is the only ore of chromium, and its compounds are of economic importance. It occurs in Silesia, Styria, Moravia, Russia, Norway, New Zealand, and the United States.

There is considerable variance in the chemical composition of these ores, the limits of which are approximately defined in the following analyses:—

	Per cent	Per cent	Per cent		Per cent	Per cent	Per cent
Cr_2O_3	39·60	51·50	51·20	MgO	9·60	16·30	12·55
Fe_2O_3	.....	......	1·45	CaO	1·30	...	3·15
FeO	21·20	14·80	13·33	SiO_2	4·50	3·80	4·95
Al_2O_3	22·80	13·20	12·80	CuO	0·20	.	....

Treatment of Chromite for Ferro-chromium.—The different methods of treating chromite are based upon the condition in which it is desired to have the final product, whether in the form of pure chromium or as the alloy ferro-chromium. In preparing ferro-chromium, the ore is first mixed with the following substances: charcoal, 12 to 15 per cent ; resin or pulverized pitch, 6 to 7 per cent ; glass scrap, 5 per cent ; and quartz sand, 10 to 12 per cent. An intimate mixture is desirable, and can be best secured by piling the ingredients in a heap, each forming a separate layer, and then removing in vertical sections to form a new heap. After repeating this process several times the mass will have a uniform appearance. The ore is then fused in a graphite, or strong clay crucible, the bottom of which is covered with a thin layer of fine glass and coarse charcoal. The cover of the crucible is sealed with clay; only a small opening should be left for the escape of gases. The ore can be reduced by a crucible furnace with good draught, but to melt the metal a gas regenerative furnace will be required. Where a Siemens furnace for crucible steel is at hand this may be employed to advantage for smelting ferro-chromium. A furnace of special construction for making chromium and tungsten, as well as their alloys, has been designed by the writer, and has been in successful operation for several years past. This furnace, which is shown in Figs. 1, 2, and 3, consists of a generator in which coke is used and two combustion chambers, each of which is connected with a pair of regenerators. The gas produced in the generator passes into a channel, whose position may be seen in Figs. 2 and 3, into which funnels are let down from above. When in operation, three of the funnels are closed by iron caps, while the fourth is connected by a U tube with one of the four funnels which are set in the gas channels along the sides of the combustion chamber. By this U tube one of the channels, and, at the same time, one side of the chamber, are provided with gas. When air is allowed to enter from the regenerator, after having been heated there sufficiently, it will kindle the gas, and a constant flame will be maintained around the crucibles. A second regenerator on the opposite side is meanwhile heated by the escaping gases.

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[1] Reprint from Mineral Industry, 1899, p. 92.

When the furnace is started fresh, it is necessary at first to heat the chamber to such a temperature as to make the kindling of the gas certain. This can be best effected by placing a small amount of fuel in the generator, and allowing the gas to enter the combustion chamber from one side only, until the chamber begins to redden. More fuel may then be filled into the generator, and after the gas has raised the opposite side of the chamber to a red heat, the flow of air and gas is reverted. The passage between the first regenerator and its flue is opened by turning a valve, and cold air is allowed to enter through the channel in the other regenerator. After closing the cold air entrance of the first regenerator, the U tube is placed on the opposite gas channel, and the flue damper of the second compartment is closed. The funnels from which the U tube has been removed are then covered over. Within an hour at the most the flow must be again reversed to the first direction, and the process is to be repeated every hour, or at shorter intervals. If the furnace is previously warmed, it will reach the melting point in a space of six to eight hours, which is the end of the operation, as the reduction takes place before the oxide comes to a melt.

After this the second chamber may be started. This is accomplished by opening the valves in the further compartment, and in the flue connecting the two chambers, setting the U tube on the inside channel, closing the flue and the valve in the first chamber, and opening the air chamber of the latter. When a new chamber has warmed sufficiently, the gas must be reversed and the valve in the connecting flue closed again. It is apparent that by this arrangement either chamber of the furnace may be charged or discharged without disturbing the work of the generator.

When the operation is completed the ferro-chromium will be found as a cake of grey metallic lustre, somewhat impure from inclusions of slag. This alloy is used almost exclusively for making chrome steel. Some varieties of steel, however, require that the chromium be freer from carbon.

Treatment of Chromite for Metallic Chromium.—To prepare the metal, a long and roundabout process is involved, by which a separation of the iron and chromium must be effected before the chromic oxide can be reduced.

Breaking the Ore. In Germany, the ore is first broken in a rock crusher, and then further treated in a ball mill of the Grusonwerk pattern. This type of mill is to be preferred, as it separates the coarse and fine material, and returns the former to the drum for further crushing. In chromate works of the United States, according to Lunge, the so-called Pnuematic Pulverizer is used. The ore, after being broken to a coarse size in a rock crusher and rolls, is fed through small hoppers into tubes, which receive a jet of steam of 12 atmospheres pressure. From the tubes the ore is blown into a chest, first passing through blast pipes, which are provided with disks pierced by holes of 3 mm. diameter. By the friction of the particles in the narrow chest a very fine pulverization is effected. The fines are carried out by the steam into a receiver, while the coarser material falls to the bottom and is again caught up by the jets. The final product is very even, and needs no further treatment.

Oxidizing Chromite by Roasting with Basic Flux. Although roasting with potash or soda is sometimes recommended in literature, it is not in accordance with actual practice. The purpose of roasting is to change the iron into insoluble oxide, and at the same time to bring the chromium into a soluble condition as chromate. A fundamental principle in this process is, that there must be free access of air during the entire operation. Care must also be taken to avoid the presence or formation of easily melting products, although a sintering of the ore, so long as its porosity is not lessened, is considered beneficial. The use of lime alone as flux has met with some success, but more often it is mixed with soda. Potash is no longer employed for this purpose. The lime, after being pulverized finely, is added partly in solution, and partly as a powder. The roasting is carried out in a long-bedded reverberatory furnace, or in the terraced-hearth Le Blanc furnace. The mixture of ore and flux is placed in the heating chamber, as far as possible from the flames, until thoroughly warmed, after which it is drawn to the hotter parts. A charge consumes about eight hours in roasting, during which a temperature of about 1,200° C. should be maintained. To heat the floor of the hearth from beneath, as has been sometimes recommended, is bad practice, and greatly shortens the life of the hearth. Great care should be exercised in constructing the hearth floor, if interruptions are to be avoided during practice. The bricks intended for the floor should be laid dry on a bed of fire-clay. On the upper terraces the floor need not have a thickness of over 125 mm., but for the lower terraces the bricks should be laid on edge so as to give double that width. The joints should be filled with fire-clay.

Various proportions of flux and ore are used. The lime sometimes reaches as high as 150% of the ore, but may be as low as 50%; the alkalies are never more than 50%. The following formula shows the change which the ore undergoes during the roasting:

$$2FeCr_2O_4 + 4Na_2CO_3 + 7O = Fe_2O_3 + 4Na_2CrO_4 + 4CO_2.$$

Lixiviation and Separation of Chromium and Iron.—The product is now treated in iron kettles, with hot water, to which sometimes a little soda is added to convert the calcium chromate to sodium chromate. The sodium chromate goes into solution, while the iron oxide and lime, being insoluble remain behind.

Conversion of Chromate to Bichromate.—By evaporation the solution is reduced until it reaches a density of 1·5; it is then converted into sodium bichromate by adding sulphuric acid: $2Na_2CrO_4 + H_2SO_4 = Na_2Cr_2O_7 + H_2O + Na_2SO_4$. It is customary not to carry the conversion to completion, 1 to 2% of chromate being allowed to remain neutral, as an excess of sulphuric acid would be injurious to the kettles. The solution is now evaporated to the point where the chromate hardens on cooling, and is then poured out into shallow pans.

Reduction of Chromate to Chromic Oxide. The hardened chromate is crushed and mixed with a sufficient quantity of sulphur and then placed in small cast-iron kettles of about 400 mm. diameter and depth, arranged in series of six or eight, over a simple grate. Iron pipes leading from the tops of the kettles serve to carry off the sulphur dioxide fumes. A small heat suffices to accomplish the reduction, and to bring the mass to a melt. It is now scooped out with iron ladles and allowed to cool.

Separation of Chromic Oxide and the Alkali Sulphates.—By treating the melt, after pulverization, with hot water, the alkali sulphates are dissolved, and the insoluble chromic oxide is then recovered by decantation and filtration.

Treatment of Chromic Oxide for Chromium.—The chromic oxide, after drying and grinding, is ready for the final process, by which it is reduced to metallic chromium. The reduction may be carried out by one of the following methods: (a) about 45% of pulverized charcoal is mixed with the oxide, and the mass then heated in crucibles in the previously described regenerative gas furnace, or in an electric furnace. If the former be used, the metal is recovered as a fine powder, which contains some carbon, both chemically combined and mechanically mixed. The melting point of chromium cannot be reached in the gas furnace, and if this is desired some form of an electric furnace must be employed. The writer first succeeded in melting chromium by means of a furnace which is described in Vol. IV of The Mineral Industry. A process of freeing chromium from carbon, as proposed by Moissan, consists in melting the chromium with sufficient chromic oxide, or calcium chromite, to convert the carbon monoxide: $3Cr_4C + Cr_2O_3 = 14Cr + 3CO$. The same principle is the basis of the Siemens-Martin process for making malleable iron. (b) An interesting method by which the oxide may be reduced without the aid of a furnace has been proposed by Goldschmidt. The chromic oxide is mixed with a quantity of aluminium sufficient for the reaction $Cr_2O_3 + Al_2 = Cr_2 + Al_2O_3$; the mass is then placed in a crucible lined with magnesia, and ignited with some compound giving a high ignition temperature, such as barium peroxide and aluminium, in the proportions

$3BaO_2 + Al_2 = 3BaO + Al_2O_3$. Upon igniting with magnesium band a violent reaction takes place throughout the entire mass, and continues until, by adding successive portions, the crucible is filled with molten metal and aluminium oxide. After cooling the chromium can be recovered as regulus of great purity. (c) A process proposed by Aschermann is based on the fact that the oxide may be reduced by the sulphur contained in metallic sulphides. It requires a quick and high heat, which can best be secured in an electric furnace. If antimony sulphide is used, the melt will be composed of chromium, the antimony being volatile. $2Cr_2O_3 + SB_2S_3 = 2Cr_2 + Sb_2 + 3SO_2$. With the fixed metals there will be an alloy, $3FeS_2 + 4Cr_2O_3 = Fe_3Cr_8 + 6SO_2$.

APPENDIX II

Experiments with Chromite at McGill University, Montreal.

A number of experiments have been made in the McGill laboratories, with chrome iron ores, under the direction of Dr. J. B. Porter, professor of mining; and while these tests may not be regarded as final, they point to the solution of difficulties, and teach many things, especially in connexion with comminution of the ore by stamps, and its behaviour in classifiers. Mr. R. H. Patterson, B.Sc., 1907, had charge of the most recent experiments (Dec. 1906 to April 1907), and an abstract of his report is hereby presented:—

"The particular material treated (a few bags of concentrates and some tons of milling waste) came from the Eastern townships, from a property six miles to the east of Coleraine village, belonging formerly to the Montreal Chrome Iron Company, but lately purchased by Mr. J. N. Greenshields, of Montreal.

"As a preliminary investigation it was thought fit to make a screen analysis on concentrates as produced commercially at the Company's mill, in order to discover the size of the grains of chrome, etc. The results of this screen analysis are as follows:—

"The sample taken weighed 2·37 lbs., and assayed 43·59% Cr_2O_3.

0·65%	stayed on the	24 mesh	44·89% Cr_2O_3
23·30%	" "	40 mesh	
25·00%	" "	70 mesh	
21·50%	" "	100 mesh	42·11% "
20·50%	" "	150 mesh	39·57% "
9·00%	went through	150 mesh	41·81% "

"These figures indicate one thing pretty clearly, that the chrome shows a great tendency to slime. It may also be noted that 30% of the material recovered is below 100 mesh, and this being the case, it is quite safe to say that with the present method used at Black Lake another 30% of fine chrome is lost in the slimes.

"The first set of experiments was then carried on with the raw ore to see how far the tendency to slime could be overcome by using different sized screens on the stamps. Three tests were run, using a 14, a 20, and a 30 mesh screen.

"The apparatus used consisted of a small steam stamp (hand fed), discharging into a rising current classifier, which sent its spigot product to a Wilfley table, and its slime across to a settling tank, the [illegible] being hand fed could not be expected to work uniformly, and the table needed continual adjusting on account of this intermittent feeding.

"The table made three products, heads, middles, and tails, which were caught, dried, weighed, and finally assayed. The slimes from the classifier were also dried, weighed and assayed; they were then treated on a Wilfley table, making heads, middles and tails; the heads were all caught and weighed to find the percentage of extraction, and samples of the middles, tails, and table slimes were taken and assayed.

"These slimes also had to be hand fed, being first well mixed with water in a tub. The result of the operation was not very satisfactory, as was only to be expected, since hand feeding was employed. If the stamp mill could have been uniformly fed in the first instance, and if the classifier slimes could have been sent direct to a second table much better results would have been obtained.

Below will be found tabulated, the results of these various tests:—

Run	Mesh	Amount treated	Heads	Middles	Tails	Classifier slime
A	14	295 lbs.	98 lbs	32 lbs.	106 lbs.	56 lbs
B	20	145 lbs	30 lbs.	30 lbs.	37 lbs.	40 lbs
C	30	145 lbs	44 lbs.	24 lbs.	26 lbs.	45 lbs

RE-TREATMENT OF CLASSIFIER SLIMES FROM ABOVE TESTS

Run	Mesh	Amount treated	Heads
AA . . .	14	30 lbs.	2.50 lbs.
BB . . .	20	27 lbs	2.75 lbs
CC	30	30 lbs.	1.75 lbs.

ASSAY VALUES—FIRST TREATMENT

[illegible]	Mesh	Heads	Middles	Tails	Classifier slimes
A	14	48·9%	24·3%	1·66%	16·6%
B	20	46·9%	21·[illegible]%	1·39%	17·1%
C .	30	47·8%	17·[illegible]%	2·62%	20·6%

RE-TREATMENT OF CLASSIFIER SLIMES

Run	Mesh	Heads	Middles	Tails	Classifier slimes
AA	14	42·[illegible]	15·8%	9·[illegible]	
BB	20	[illegible]	17·0%	7·[illegible]	
CC	30	44·[illegible]	16·4%	[illegible]	

"Next, leaving the middles out of the question for the time being, the percentage of recovery was determined by calculating the amount of Cr_2O_3 in the original lots treated, and the amount of Cr_2O_3 in the three head products as above, and from these the percentage of recovery in each case as follows:—

Mesh	Extraction
14	76·5%
20	57·4%
30	63·0%

"These figures, of course, do not give the exact percentage of recovery, as no account has been taken of the heads that were recovered by re-treating the middles; but it is evident that the result in test A is far and away ahead of the other two, for, not only is the percentage of recovery better, but the middles themselves are much richer, while the slimes are much less in quantity.

"It had been intended to follow up the tests A, B and C by a run on middlings from the mill at the mine, but owing to the failure of the Company to send in a large enough sample, the next experiment was carried out upon the middles made by the Wilfley table in the several experiments detailed above. These middles were not as representative as would have been the middles from the Montreal chrome mill, but the experiment will give some idea of what could be done on the actual mill middles.

"The middles, totalling 110 lbs., were mixed and crushed by rolls to 40 mesh; a sample was taken and assayed, and the ore then treated on the Wilfley table, with the following results:—

TREATMENT OF RE-CRUSHED MIDDLES

	Heads	Middles	Tails	Slimes
Weights	46 lbs.	30 lbs.	15 lbs.	18 lbs. (not saved)
Cr_2O_3	46·6%	16·7%	6·6%	24·7%

The original sample assayed 32·29% of Cr_2O_3.

"Thus we see that a good separation was obtained on the table, with fairly good values in the concentrates. The loss of 24·7% in the slimes is rather high, but this is only to be expected when using rolls as a means for such fine crushing.

"In treating these middles, hand feeding was employed, which, at its best, is a very rough method where accurate work is desired.

"Now by calculating the percentage of extraction in the re-treatment of these middles, we see that we can save 67% of the values in them, hence we can now figure back to the actual percentage of extraction in each case from start to finish, assuming that 67% of the values in the middle product is saved after re-treatment.

"On the 14 mesh, the actual total extraction is 85% of original values.
"On the 20 mesh, the actual total extraction is 74% of original values
"On the 30 mesh, the actual total extraction is 71% of original values."

Mr. Patterson summarizes his results as follows:

"First: that the best screen to use on the ore in question would be a 14 mesh, or some other large size, in that it yields the highest percentage of extraction, the maximum amount of concentrates with the highest values, and the least loss by sliming of the three screens under consideration.

"Secondly: that by crushing the middles and re-tabling them, a fairly high concentration is obtainable as regards values, and a higher ratio of concentration than any of the original ore treated."

Dr. Porter, under whose direction the above, and also quite a number of additional experiments have been made, expresses himself on the subject of chromite concentration as follows:

"The usual method of concentration is to crush the ore in stamp mills, to 20, 25 or 30 mesh, and to treat the resultant pulp on Wilfley tables. Many other mill schemes have been used, as, for example, rolls for crushing, medium and fine; jigs for treating a comparatively coarse product, buddles in place of tables, etc., and even magnetic and electrostatic apparatus have been tried for raising the tenor of concentrates produced by the ordinary process. In this connexion a large amount of experimental work has been done at the McGill University laboratories with a view to developing practical improvements, but as yet no radical change in method has proved satisfactory, and it is probable that the best commercial results can be obtained by improving the present practice, using stamps of the best weight, drop, and height of discharge, etc., as determined by experiment, and treating the pulp on Callow or impact screens of suitable mesh as a preparation for Wilfley tables for the coarse sizes, and either Wilfley or some other tables for the fines.

"The chromite occurs in rounded grains, and differs from most minerals which are concentrated in being harder than the gangue material. These advantages offset to a great extent the difficulties which would otherwise be experienced in separating it from a mineral differing from it so little in specific gravity as serpentine.

"The size of the grains differs in the different deposits, and so also does the proportion of chromite to gangue. The average rock milled contains probably 30 per cent Cr_2O_3, but no two deposits are alike, and in most cases each body of ore has considerable masses of very low grade material in or near it, and it is probable that the tenor of rock milled will gradually decrease as methods are improved. The crushing should be to a comparatively small size—in most cases 20 mesh may be taken as a standard but experiment proves that for each ore there is some screen size below which the slime losses become excessive, and above which the production of a middle product is too great. In this connexion it is interesting to note that even when the screen is too coarse there is a fair production of material of the right size, owing to the comparative strength of the chromite grains as compared with the surrounding serpentine.

"The common practice is to send the pulp directly from the stamp battery to the tables, but this causes undue losses even of coarse stuff, and greatly lessens the recovery of fine material. An improved practice is to classify the pulp, and send the coarse stuff to one set of tables and the fine to another. This does fairly well, but it is probable that a considerable further improvement can be effected by introducing screens of a mesh to be determined by experiment, between the battery and the classifier. The use of screens for this purpose has heretofore proved too expensive, but the recent invention and successful development of the Callow screen makes it probable that it will prove commercially satisfactory. These screens would produce a coarse material, which might possibly be rich enough to market direct in cases where fibrous serpentine does not occur. Tables would, however, improve even the best product possible from screens. The fines from the screens should go to finer screens, or more cheaply and almost as well, to classifiers, and then to tables adjusted for finer material.

"A common feature of chromite concentration is the comparative ease with which a fairly rich material can be made, and the extreme difficulty of raising the grade of this concentrate more than two or three per cent. For example, a certain rock carrying 28 per cent of Cr_2O_3 can be easily and economically treated to give a concentrate of 45, or perhaps 46 per cent. By very careful work, and a re-treatment of middles, the concentrate could be brought up to 48 per cent, but no amount of care, even with the most elaborate system of dressing, will produce a concentrate of 50 per cent Cr_2O_3.

"The above peculiarity is, of course, due to the fact that the grains of chromite are themselves impure, and the best that can be done is to free them from any accompanying serpentine, but the matter is one which must be kept in view when mills are being designed or remodelled.

"The maximum possible concentration is perhaps 3 or 4 per cent higher than the concentration which ordinarily gives the best profit, as the expenses and losses increase rapidly as the tenor is raised, but if the concentrate can be brought up to 50 per cent these expenses are likely to be justified, as the price of a concentrate of this tenor is considerably higher than that of lower grade stuff.

"In conclusion, it may be said that the concentration of chromite, although apparently in a somewhat crude stage of development, is really fairly well suited to the present supply of ore and demand for material, and that future developments are more likely to be in the way of improving and cheapening present methods than of devising novel schemes for treatment."

BIBLIOGRAPHY.

Am. Journal of Science Vol. VII, 1899, p. 281

Am. Journal of Science - 2nd series, Vol. XIV, 1852, p. 47.

Ann. Chem. et Phys. --4th series, Vol. XXI, 1869, pp. 90-100.

Donald, Dr. J. T.--"Chromic Iron, its properties, mode of occurrence and uses." Journ. Gen. Min. Assoc. of Quebec, 1894-95, p. 108.

Donald, Dr. J. T.—"A notable Canadian Deposit of Chromite." Journ. Can. Min. Inst., 1899, p. 25.

Edwards, W. H. – "Notes on the production and uses of Canadian Chrome", Journal Can. Min. Inst., 1906, p. 35.

Geol. Survey of Canada, Reports of ---1853, p. 422; 1858, pp. 154-164; 1863, pp. 43, 253, 266, 750, 504, 614; 1872-73, p. 128; 1876-7, p. 483; 1877-78, p. 26G; 1882-84, p. 20F; 1888-89, p. 111K, pp. 28 and 29T; 1892-3, p. 27R; 1896, p. 21S; 1897, p. 27S; 1900, p. 24S.

Glenn, William "Chrome in the Southern Appalachian Region". Trans. Amer. Inst. of Mining Engineers, 1895, page 481.

Glenn, William—"Chromic Iron with reference to its occurrence in Canada." U.S. Geological Survey, Seventeenth Annual Report, Part III, page 262.

Min. Res. N.S. Geological Survey —1900, Pamphlet on Chrome Iron Ore.

Min. Res. N.S. Geological Survey -1901, pp. 941-945.

Min. Res. N.S. Geological Survey -1905, p. 122S.

Mineral Industry—1893, 1895, 1897, 1898, 1899, 1900, 1901, 1902, 1903, 1904.

Obalski, J. Chromic Iron in the Province of Quebec, 1898.

Obalski, J. Mining operations in the Province of Quebec for the year 1903, pages 13-47.

Obalski, J. - "Chromic Iron in Quebec", Journ. Gen. Min. Assoc. of Quebec, p. 111, 1894-95.

Pratt, Dr. Joseph Vol. XXIX, 1899, pp. 24-30, U.S. Geol. Survey.

Pratt, Dr. Joseph– "Corundum and the Peridotites of Western Carolina", 1905 (North Carolina Geological Survey) page 369.

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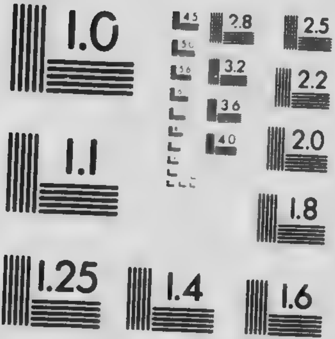

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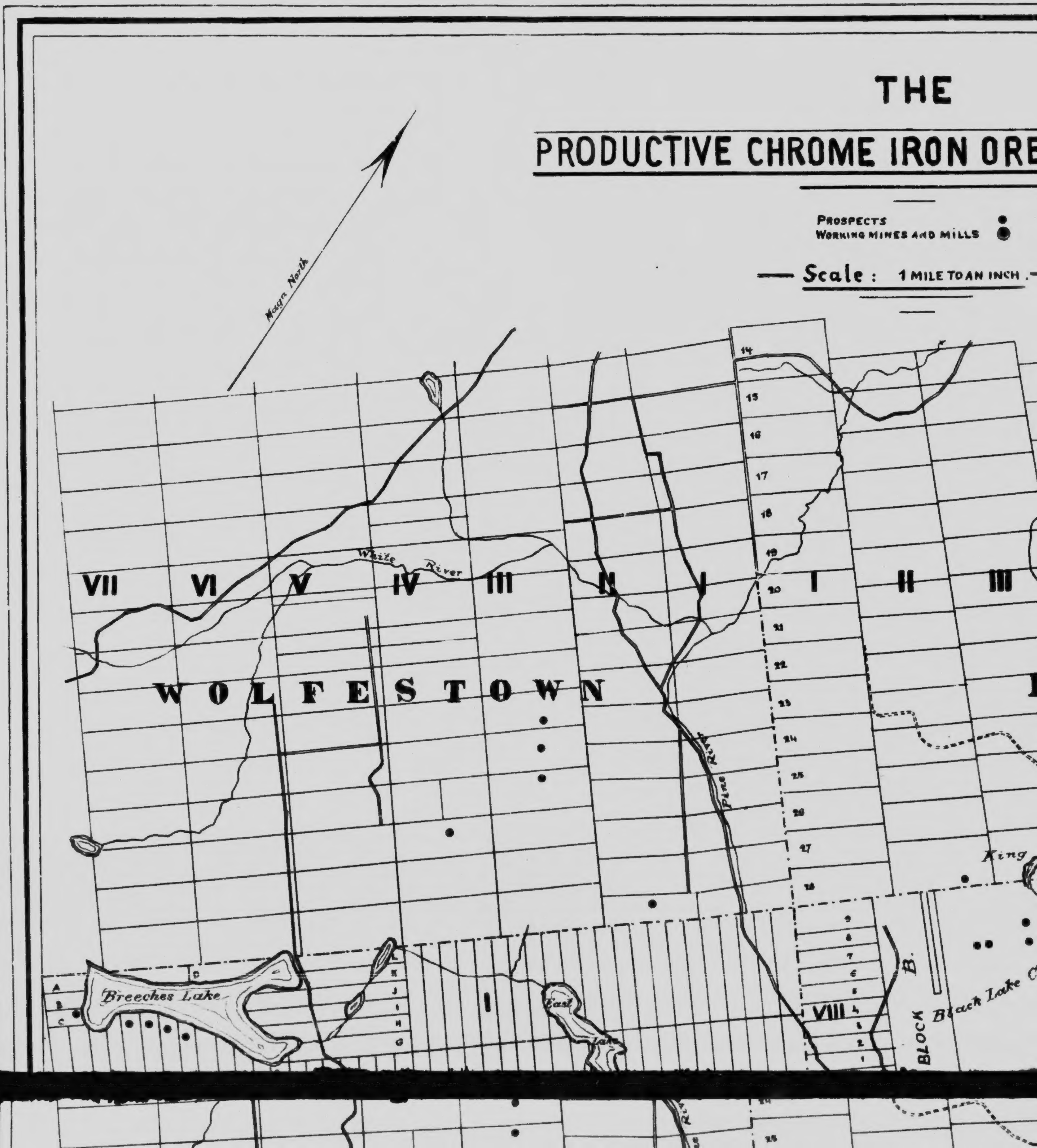

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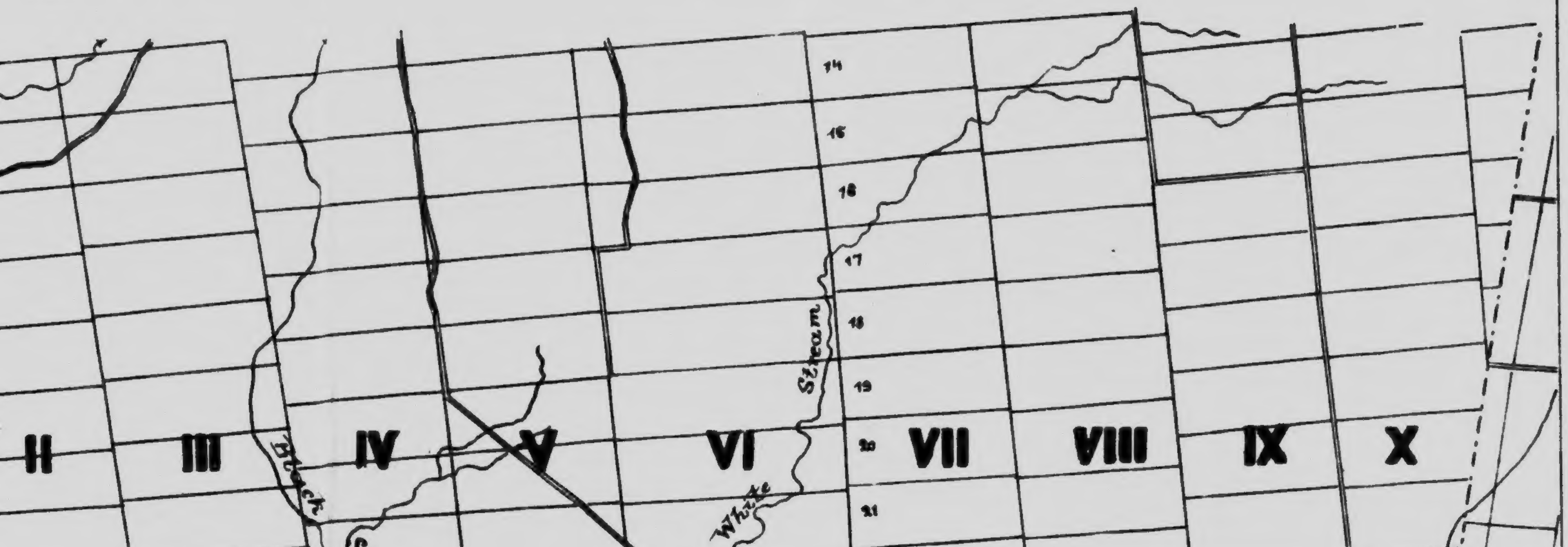

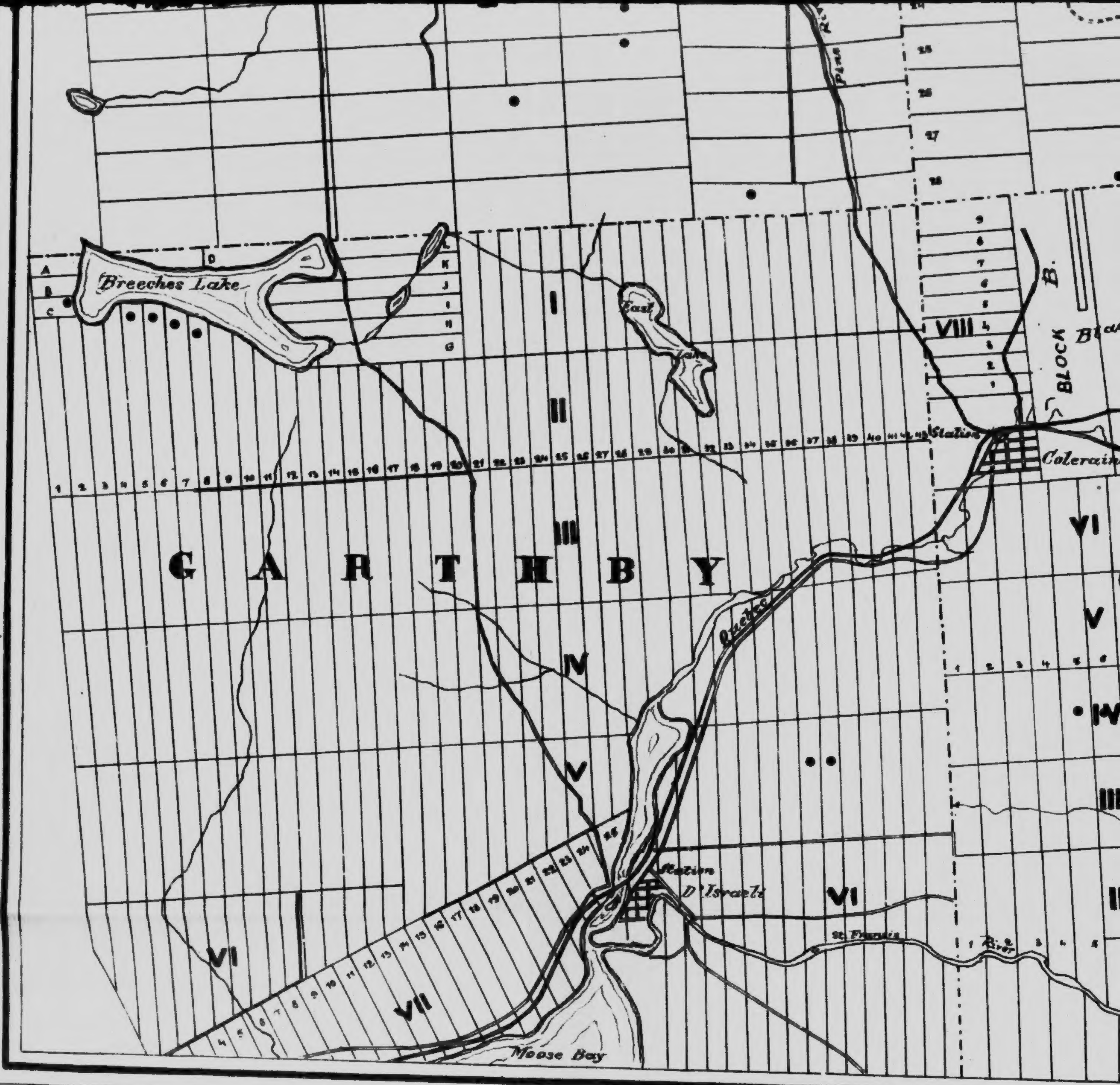
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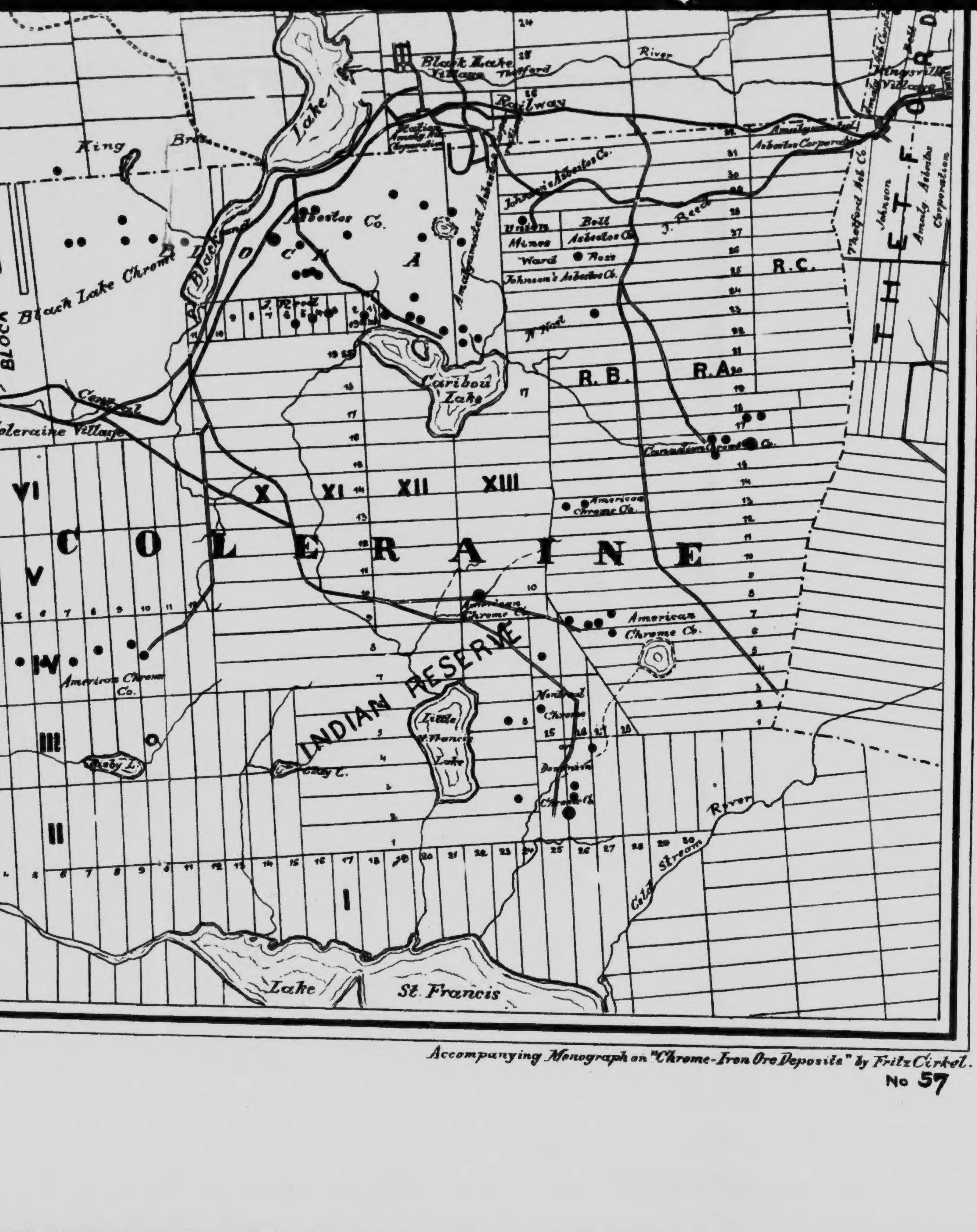

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